

## Using Telecommunication Instructional Modelling System (TIMS) in Communications Systems Course

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## Abstract:

Conventional courses in communications systems use lecture and readings to explain the theory, and assign paper based problem sets of theory and math, supplemented with limited Matlab and Multisim based labs. Software based simulation studies are a useful learning tool, however, computer simulations cannot model all aspects of the behavior of actual systems.

Telecommunication Instructional Modelling System (TIMS) is an advanced system for telecommunications training. TIMS is a rack and module system, in which modules perform a basic communication or signal processing function. For example, there are adders, multipliers, filters, samplers, and signal generators. TIMS provides students with a way of prototyping communication and signal processing systems in the laboratory that helps understanding.

TIMS would provide a more "real world" experience for the students compared with only software simulations. In an attempt to give students more hands-on experience with the theories and concepts of analog and digital communications, lab exercises using the TIMS were developed. A recent offering of this course gave the students a TIMS lab after each topic was introduced: amplitude modulation/demodulation, frequency modulation/demodulation, sampling, ASK generation/demodulation, BPSK generation/demodulation, FSK generation/demodulation. TIMS units are hardware training systems, with which the students build the circuits at a block diagram level, and observe the results using oscilloscope.

Evaluations were based on student surveys (course evaluations) and student work (assigned homework, exams and labs). Recent offerings of this course taught in the traditional way by the same instructor resulted in only 60.8% of the students receiving a "B-" or higher grade for the course. In the first iteration of TIMS system, the number of students who received a "B-" or better increased to 77.8%. Moreover, 96.3% of students "agree" or "strongly agree" that TIMS helped them to better learn the course content. 92.6% of students "agree" or "strongly agree" that TIMS increased their interest in the subject.

## Introduction

Courses in communication systems are based on complex and mathematical concepts that are hard for many undergraduate engineering students to fully understand. Typical pedagogy involves theory with lectures and readings, mathematical homework, and exercises with computer simulations. The computer simulations help, but have enough differences with real voltage signals to hinder full understanding for some students.

To provide direct analog and digital communication experience for students, Tim Hooper developed the first version of Telecommunication Instructional Modelling System (TIMS) in 1971. TIMS is a hardware training system, designed specifically for telecommunications and signal processing courses that requires only an oscilloscope to use the system<sup>[1-3]</sup>. TIMS allows

students to experiment with real world electrical signals in a way that is doable and understandable for more students compared to utilizing only theory and simulations.

Courses for undergraduate engineering students in communication systems are usually upper level courses at many universities. Such courses provide an introduction to undergraduate students in the fundamentals of communication systems. Communication systems involve an original message being carried from one point to another, using either analog or digital modulation. A laboratory component is often included in the course. Traditionally, the labs had the students utilize computer simulations of the signals with Matlab and Multisim for amplitude modulation/demodulation, frequency modulation/demodulation, sampling, and phase shift keying. PC based simulation studies are a useful learning tool. However, simulations cannot model all aspects of the behavior of actual systems. The learning experience for students may miss the insight and intuition that may have developed if they had directly experienced with real electrical communication signals.

TIMS environment is reported to have been used in some universities around the world <sup>[1-2, 4]</sup>. TIMS allows students to learn about the concepts of the many sub-sections of telecommunications and gives a more hands-on experience. This paper presents examples and effectiveness of TIMS labs that were developed for and used within a senior-level communications systems course, and compares the results with a prior, more traditional course offered by the same instructor.

### **Design of TIMS Labs**

The Engineering Communication Systems course discussed in this paper is for senior students in electrical engineering. This course is a 3 hour lecture, 2 hour lab, 4 credit course. The following topics are introduced to students: amplitude modulation, angle modulation, probability and random processes, effect of noise on analog communication systems, analog to digital conversion, digital modulation, and digital transmission.

Inspired by an ASEE workshop at University of Rhode Island that focused on combining MATLAB simulation with TIMS<sup>[2]</sup>, six TIMS labs were developed and used in the course. The six labs include: amplitude modulation/demodulation, frequency modulation/demodulation, sampling, amplitude shift keying modulation/demodulation, binary phase shift keying modulation/demodulation, frequency shift keying generation/demodulation. The students did each lab with 2 students per group. Moreover, four of the previously developed and utilized Matlab computer simulation labs were selected, modified and used to supplement the TIMS labs. The topics of the simulation labs include: system property – linearity/nonlinearity, filter design, angle modulation/demodulation, and distortion analysis.

With the TIMS systems, communication signals are formed and manipulated by patching together TIMS modules. Some modules represent fundamental telecommunications system building blocks that are the hardware realizations of telecommunications systems. Other modules are signal processing schemes.

As an example of the developed TIMS labs, the first TIMS lab was amplitude modulation/demodulation. Figure 1(a) shows the block diagram for amplitude modulation, for which Figure 1(b) shows the module connections. For recovering the message, Figure 2(a) shows the block diagram of the ideal envelope detector, for which Figure 2(b) shows the module connections.

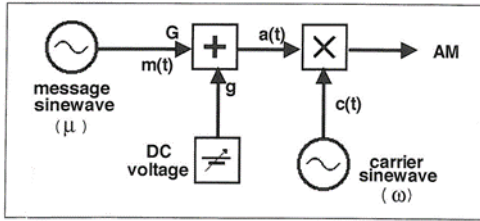


Figure 1(a) Generation of AM. A generated sine wave has a DC offset added. The resulting signal is multiplied by a carrier sine wave.

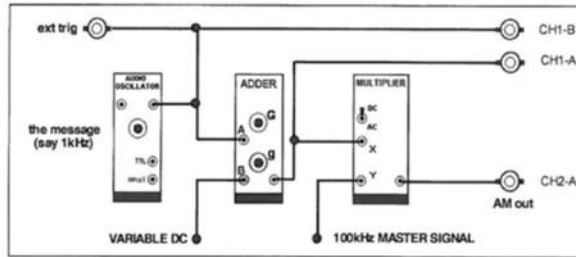


Figure 1(b) Module connections for schematic of Figure 1(a)

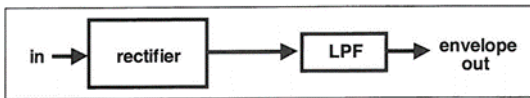


Figure 2(a) Envelope recovery arrangement. An amplitude modulated signal goes through a rectifier followed by a low pass filter to isolate the message signal.

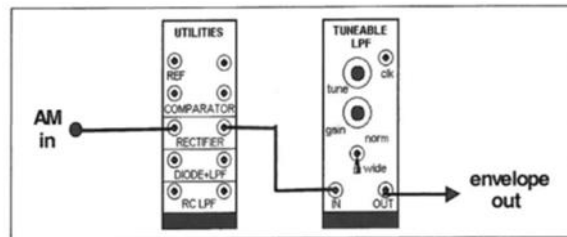


Figure 2(b) Module connections of envelope detector

An image of the TIMS connected for this lab is shown in Figure 3. The TIMS rack system consisted of the following equipment: (a) EMONA TIMS, (b) Agilent MSO-X 3102A Oscilloscope. Three modules Audio Oscillator, Adder, Multiplier were used for amplitude modulation. Utilities, and tunable low pass filter (LPF) were used for amplitude demodulation. Students used TIMS modules to generate amplitude modulated signal with 100 kHz carrier. They varied the amplitude and frequency of the modulating signal, and modulation indices to see the results on oscilloscope in both time and frequency domains. Then the students demodulated the modulated signal and observed it in time and frequency domains. Figure 3 shows an image of the TIMS modules and connections that implement modulation and demodulation.

Figure 4(a) shows the time and frequency domains of modulated signal, and time and frequency domains of demodulated signal are shown in Figure 4(b).

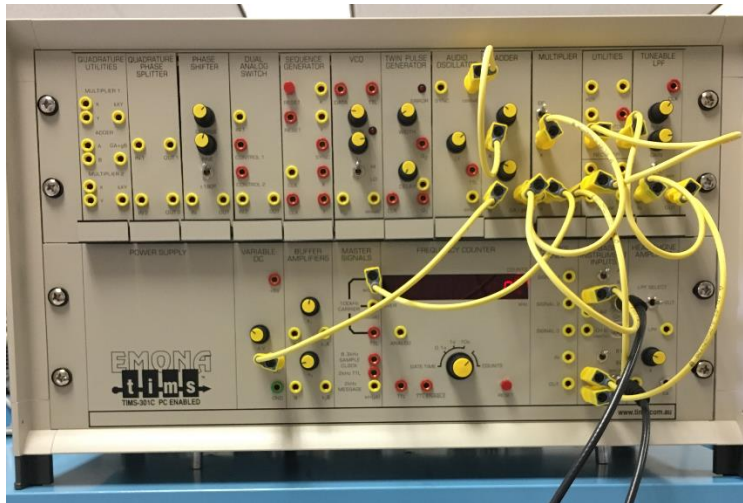


Figure 3 TIMS platform for amplitude modulation and demodulation.

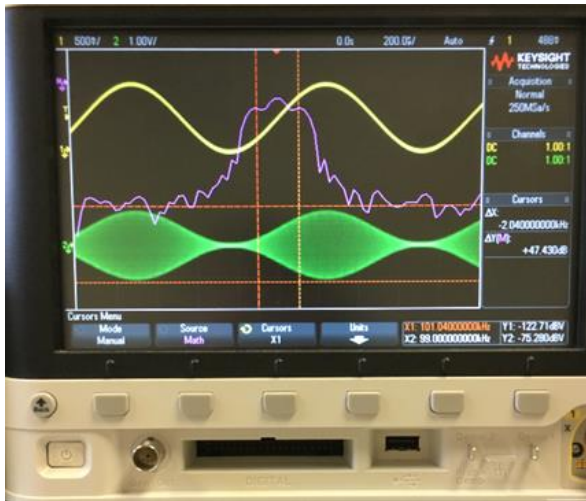


Figure 4(a) Amplitude modulated signal in time and frequency domains. The upper trace in yellow is the message. The lower trace in green is the modulated signal. And the middle trace in purple is the frequency domain representation of the modulated signal.

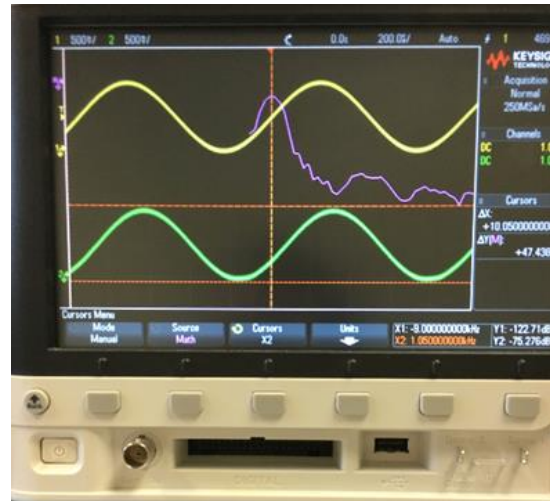


Figure 4(b) Amplitude demodulated signal in time and frequency domains. The upper trace in yellow is the message. The lower trace in green is the demodulated signal. And the middle trace in purple is the frequency domain representation of the demodulated signal.

Another developed lab module was frequency modulation/demodulation. Frequency modulation was implemented with a voltage controlled oscillator – VCO, and demodulation is done with a zero-crossing detector. The frequency deviation is set using the method of Bessel nulls when the message is sinusoidal [1].

The remaining four developed TIMS lab modules were sampling, amplitude shift keying modulation/demodulation, binary phase shift keying modulation/demodulation, and frequency shift keying generation/demodulation.

## Results of TIMS Labs

### *Course assessment of TIMS labs:*

Table 1 provides the students' final grades when Engineering Communications Systems were taught either with traditional labs or with TIMS based labs by the same instructor. There were 28 students for traditional labs and 27 students for TIMS labs.

Table 1: Students final grade distribution

Final grade	A and A-	B+, B, and B-	C+, C, and C-	D+ and D	F
Traditional labs	17.9%	42.9%	25.0%	7.1%	7.1%
TIMS labs	25.9%	51.9%	14.8%	7.4%	0%

When students studied the course with the traditional labs, 60.8% of the students received A/A- and B+/B/B-. In the first offering of the course using the TIMS labs, the number of students who received A/A- and B+/B/B- jumped to 77.8%. The number of students who failed the course declined from 2 to 0.

### *Student feedback of TIMS labs:*

A survey was conducted the last week of the semester to collect feedback to evaluate what the students thought about TIMS labs.

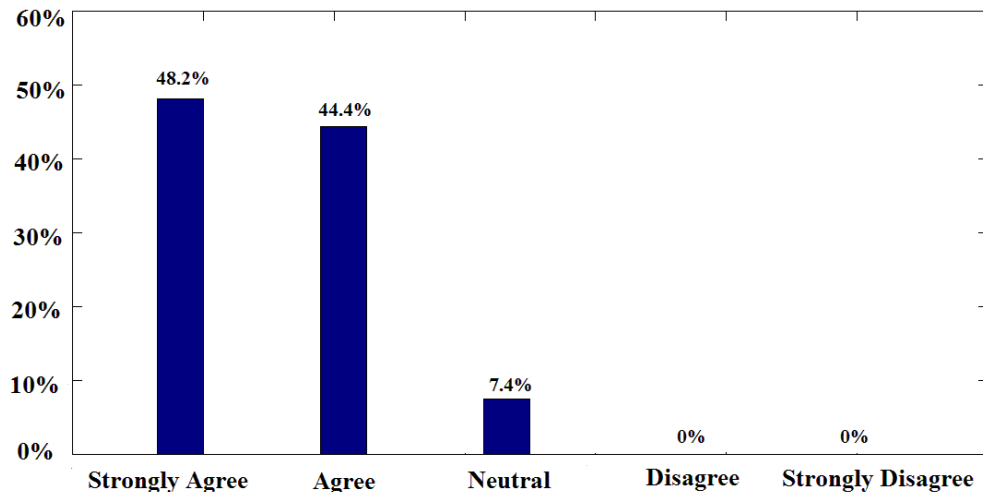


Figure 5: Results for question "TIMS labs increased my interest in the subject."

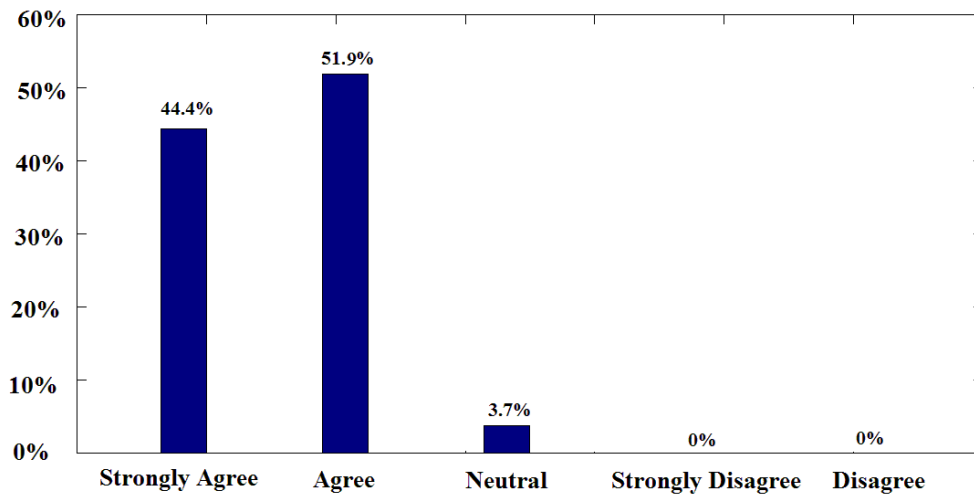


Figure 6: Results for question “TIMS labs helped me better to learn course content.”

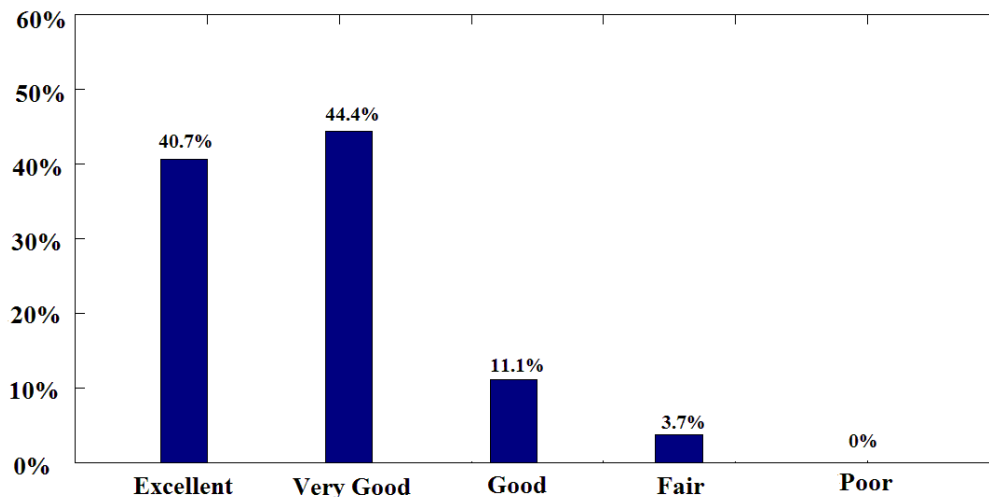


Figure 7: Results for question “What overall rating would you give TIMS labs.”

Based on the survey, 92.6% of students “agree” or “strongly agree” that TIMS labs increased their interest in the subject (Figure 5), 96.3% of students “agree” or “strongly agree” that TIMS labs helped them better to learn course content (Figure 6), and 85.1% of the students thought TIMS labs were excellent or very good (Figure 7).

### Discussion and Conclusions

Some examples and effectiveness of TIMS labs added to communications systems course for electrical engineering have been shared in this paper. The TIMS provides a practical understanding of the abstract concepts of modulation and demodulation and their related time and frequency components. TIMS experience for the students not only reinforces block diagram

view of important communication concepts, but also makes students feel that they are engaged in “real-world modulation/demodulation”.

Based on our course assessment and student feedback, TIMS labs seemed to encourage students to be more active participants in the learning process, increase their understanding, and improve their performance. Also, TIMS labs usually involve group work. Engineers are now, more than ever, expected to collaborate and cooperate with their peers <sup>[5]</sup>.

Communication courses attempt to have the students develop an understanding of several different abstract layers of the systems. For example, math equations for communication are explored in lecture, textbook, and homework. Computer code implementing the math equations can be explored by having the students program script code in Matlab. Conceptualizing complex systems as connected basic telecommunication blocks is explored in diagrams, and can be implemented in either software or hardware. Software can implement blocks with computer simulation that has each block encapsulated as a function. Hardware can implement blocks either by having the students build each block using basic components or by having the students connect provided hardware circuit blocks, such as TIMS.

The TIMS system provides each hardware telecommunication block as a “black box” to the students. This allows the students to combine several blocks in one lab period, including generating input signals and analyzing the output signals. However, the students may not be able to understand what is inside each black box. The students could build each block themselves using a prototype board and basic components, but that may take the entire lab period to assemble, trouble shoot and make even one functioning block, leaving no time for combining the blocks, or generating the input signals and analyzing the output signals.

Having a combination of Matlab simulations (where the students implement the math algorithms of communication with script code) and TIMS based hardware labs (where the students combine the hardware modules and pass through real analog signals) seems to be a good combination to enhance student engagement and learning. One idea for improvement is to add to this lab sequence one hardware lab, where the students use basic circuit components to make a telecommunication block. This may help the students understand that all the blocks are composed of similar hardware circuits.

Another future direction would be to assess whether the students who have benefited from the TIMS experience will continue to be more successful in their future study.

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