

## **BYOE: Utilizing the EET Communication Simulator**

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## **Abstract**

It can be challenging to effectively teach a first course in communication systems to electrical engineering technology (EET) undergraduates. One reason for the difficulty is that complex mathematical and signal-processing concepts must be introduced without the mathematical rigor expected in a traditional electrical engineering course. To make life easier for both the instructor and student, the EET Communication Simulator was developed. This is a software simulator that can run via any of the modern web browsers. The primary hypothesis of the research and development project was that students would learn communication principles better if they were presented with visual representations of the complex mathematical functions and corresponding signal representations. There were two objectives of the project: (i) create a software communication systems simulator that an instructor can utilize in a pedagogically effective manner, and ii) create a user-friendly learning tool for communication systems students. Several groups of students worked to improve the simulator over a period of two years. The other students, who were not directly involved in the project, participated in the testing and evaluation of the simulator. Their feedbacks were obtained through a survey. The results of the survey, shedding light on students' attitudes and perception with regards to the simulator, are presented in this paper.

A live demonstration of the software simulator will be presented at the conference. Attendees will be given an opportunity to 'test drive' the simulator.

## **Introduction**

There are several approaches for the instruction of an introductory course in telecommunication systems. In a typical electrical engineering program a lot of attention is placed on analytical models and the underlying mathematics involved. This approach assumes that the student has sufficient mathematical capability and or background to fully grasp the models and equations discussed in class. Software such as MATLAB and Simulink are sometimes utilized in lectures to make it more appealing through visual representations of communication signals and systems. Nevertheless, students may struggle to understand some of the abstract concepts. This is especially true in the electrical engineering technology classroom where the focus is more on a 'hands on' approach with less mathematical rigor. In such a scenario as this, the question was asked, "how can students be engaged in the classroom in a way that enhances their learning of telecommunications fundamentals?" A novel approach was presented as a response to the preceding question. The idea was to allow the students to design an educational simulator for themselves that facilitate the following learning paths: (i) an instructor-led tool that could visually demonstrate the various mathematical models introduced in the classroom and ii) a student-centered tool that one could use at his/her own pace to reinforce or learn the theoretical concepts presented in the classroom. The basic premise of the project was that the students would learn better through visual representation of the complex mathematical equations that model various stages of signal processing in telecommunication systems. It was hypothesize

that if students are able to see the waveforms that are represented by the equations and algorithms, and are able to interact with the models by changing various parameters and instantly seeing the corresponding system change, then they may appreciate the underlying mathematics and learn the concepts easier and better. Also, allowing the students to design the tool for the instructor encourage them to determine what aspects of the course they had difficulty learning, and how they believed this could be remedied.

### **Popular Software Tools used in Introductory Telecommunications Systems Courses**

In this section, some of the most popular software tools that are used in telecommunication courses are introduced. Afterwards, a case is made as to why it was necessary to develop a customize telecommunications simulator. Telecommunication is a vast discipline. To simplify our presentation we have grouped the software tools in 3 categories: (i) signal processing & system modeling software tools, (ii) signal transmission software tools, and (iii) data communication and networking software tools.

To model signal processing and system modeling MATLAB<sup>1</sup> and Simulink<sup>1</sup> are frequently used. MATLAB is a powerful high level programming language particularly suited for technical computation. The software includes computation, plotting, viewing and programming in a user-friendly environment. Simulink has an interactive environment that facilitates the modeling and simulation of dynamic systems. The software allows the user to build entire systems by using standard built-in blocks or customized blocks (sub-system). Together, MATLAB and Simulink provide powerful integrated environment for simulation, modeling and prototyping.

For signal transmission simulation, Microwave Office<sup>2</sup>, a frequency domain simulator, is used extensively in academia and industry. Features include electromagnetic simulation, physical layout, and noise analysis. Riverbed Modeler<sup>3</sup>, formerly OPNET Modeler, offers a virtual environment for data communication and networking. The software has an extensive library with network devices that mimic real systems.

In addition to the aforementioned software tools, other simulators have been developed and utilized by academics. Many of these were developed using the aforementioned commercial tools as the platform. Kavianpour<sup>7</sup> demonstrated the use of LabVIEW for teaching several engineering courses in signal processing, digital circuits, microprocessors, communications, and programming language. Andreatos and Zagorianos<sup>8</sup> developed a MATLAB graphical user interface (GUI) application for teaching automatic control systems. This tool allows the student to experiment with different sets of parameters to improve their learning of a typical control systems of an aircraft. Venkatalakshmi *et al.*<sup>9</sup> discussed the use of MATLAB and Advanced Design System (ADS) tools for teaching the Fourier transform algorithm to communication engineering students. However, none of these tools developed specifically addressed an introductory course in Telecommunication. Furthermore, they did not address our specific needs nor design objectives.

## Project Approach

The software simulator was developed over a period of two years with two distinct year groups and three distinct project groups. In the first year, two class project teams, each with three students, were selected. The instructions given were to design a simulator that the instructor could use in his lecture to assist in making the abstract concepts, such as modulation, easier to understand. Also, students should be able to use it at their own pace to better understand the theoretical concepts through the use of visual representation of complex signal waveform. The groups freely choose the design and programming software that they were going to use to implement their ideas. In the first year, one group selected LabVIEW to develop their simulator and the other decided to use MATLAB. Student users of the simulator software were surveyed. In the second year, a third group of students used JavaScript to create their simulator. They incorporated the feedbacks and analyses of the prior surveys to guide their development process.

## Example of an Experiment

The EET simulator was specifically designed as a teaching and learning tool. Students can use it to visually explore the underlying mathematics and signal processing in analog and digital modulation schemes. Instructors can use it as a tool to translate abstract mathematical functions into visually represented signal waveform. The following is an example of a short in-class experiment that can be done.

**Step 1:** Using the viewer control panel insert the following values into the appropriate parameter input box. (See figure 1 below).

**Mode:** Analog to analog; *this indicates the nature of source and output data*

**Type of Message waveform:** Sine

**Message Signal Frequency:** 1; frequency is stated in Hertz

**Message Amplitude:** 1

**Modulation:** AM; *amplitude modulation*

**Question 1a:** Write the equation that represents the message signal waveform:

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**Question 1b:** Write the equation that represents the carrier signal waveform:

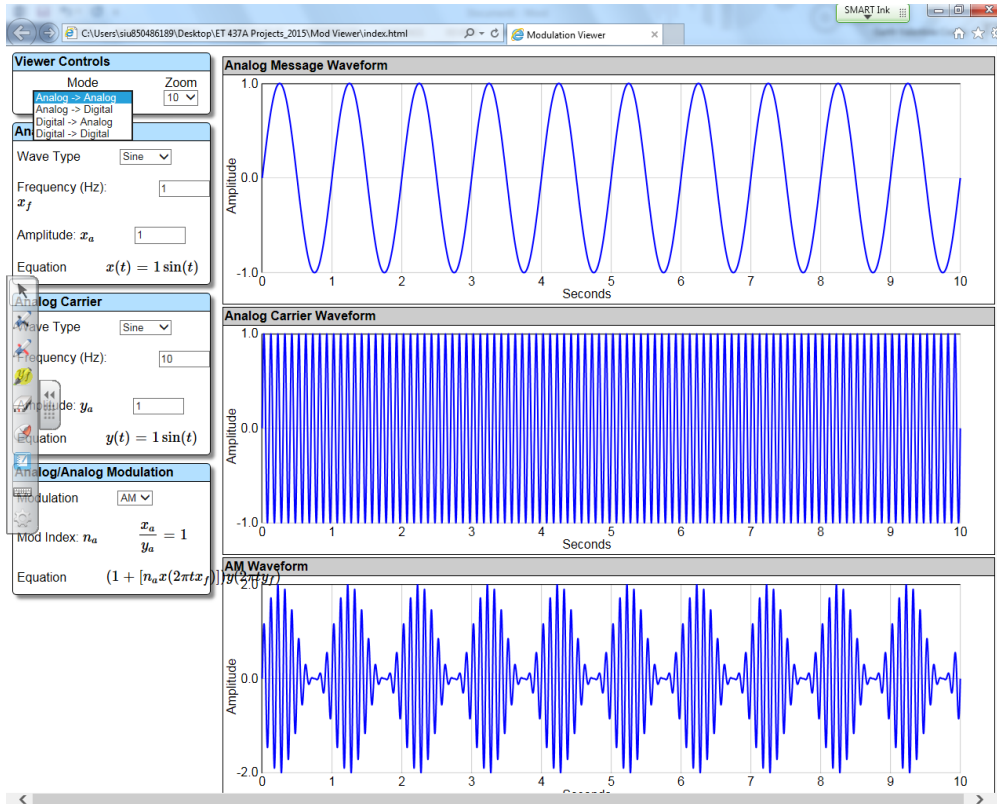
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**Question 1c:** Write the equation that represents the amplitude modulated signal waveform:

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**Step 2:** Increase the carrier signal frequency in increments of 10 until the frequency reaches 100Hz.

**Question 2a:** As you increased the carrier signal frequency, what happens to the message signal waveform? \_\_\_\_\_



**Figure 1. EET Communication Simulator- AM Modulation**

**Question 2b:** As you increased the carrier signal frequency, what happens to the modulated signal waveform? \_\_\_\_\_

**Question 2c:** As you increased the carrier signal frequency, what happens to the maximum amplitude of the amplitude modulated signal waveform?  
\_\_\_\_\_

### **Step 3:**

**Question 3a:** Write the equation for the modulation index.  
\_\_\_\_\_

**Question 3b:** Based on your response to question 3a, what do you expect to observe about the modulated signal waveform if you increased the carrier signal amplitude while keeping every other parameter constant? \_\_\_\_\_

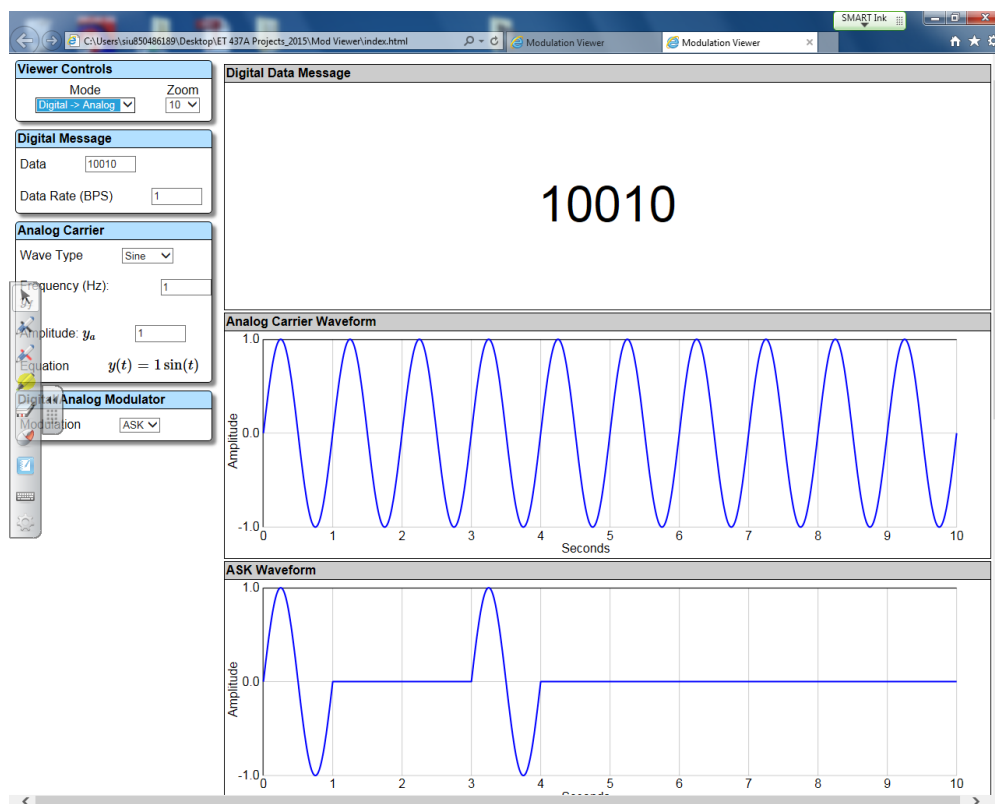
Use the simulator to check your response.

**Question 3b:** Based on your response to question 3a, what do you expect to observe about the modulated signal waveform if you decreased the message signal amplitude while keeping every other parameter constant? \_\_\_\_\_

Use the simulator to check your response.

## Design & Operation

The simulator was design such that the instructor or students could see visual representations of mathematical equations. This allowed the students to understand the various steps in analog and digital modulation techniques, including the ability to see how various parameter such as carrier signal frequency impact the modulated signal. Figures 1 to 4 show snapshots of the simulator in action.



**Figure 2. EET Communication Simulator- ASK Modulation**

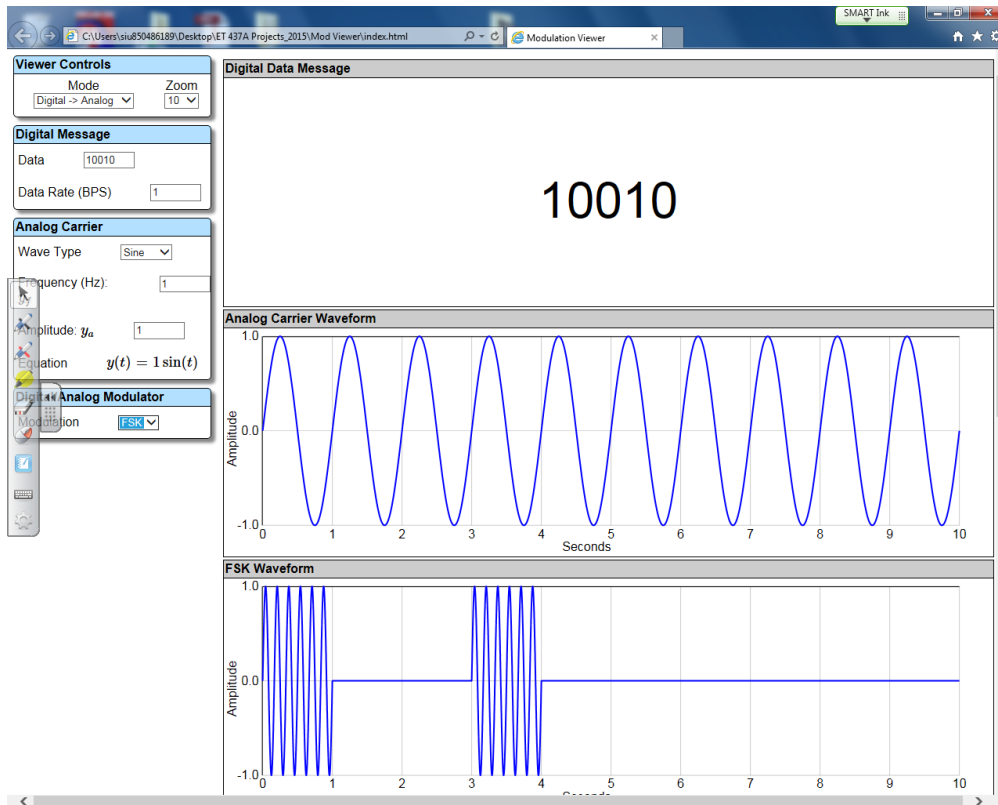


Figure 3. EET Communication Simulator- FSK Modulation

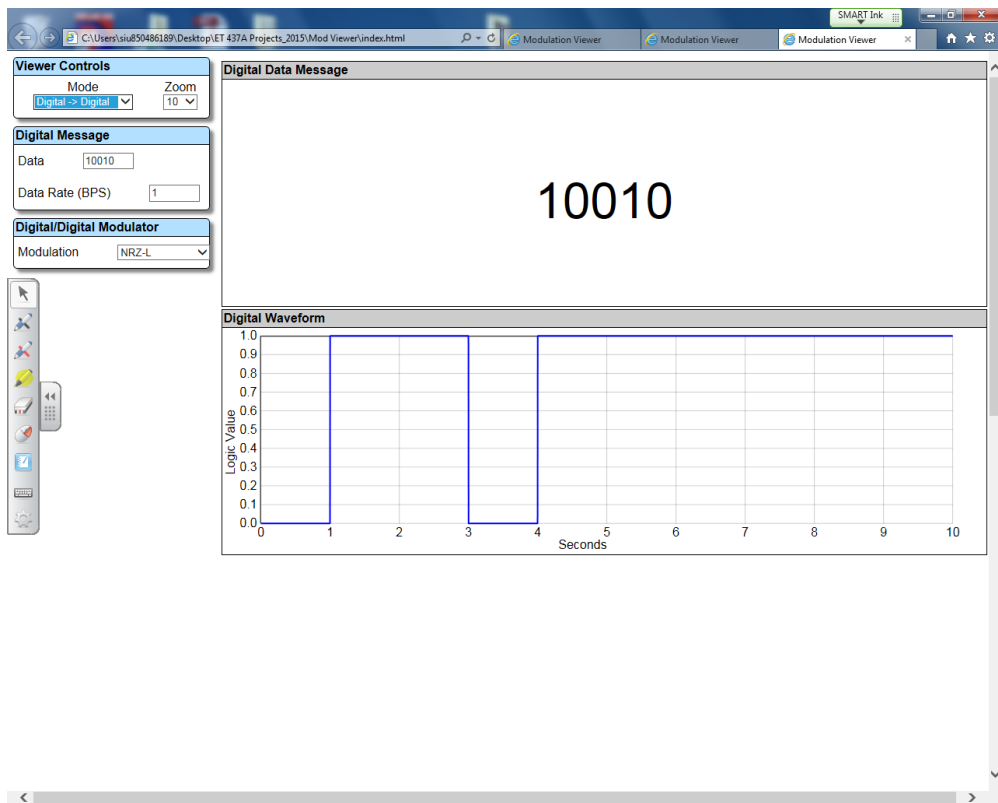


Figure 4. EET Communication Simulator- NRZ-L Digital Signal Encoding Format

The simulator allows students to visualize analog and digital modulation techniques. It allows the user to input analog or digital data (message) and see the corresponding visual representation of the output for analog modulation or digital signal encoding. Common analog modulations techniques such AM and FM are included. Several digital signal encoding formats are implemented, including the NRZ-L, NRZI, Bipolar-AMI, Pseudoternary, Manchester and Differential Manchester. The simulator dynamically adjusts the signal waveforms as parameter values are modified by the user. On the left-hand side (see Figures 1 to 4) of the simulator user interface, the end-user is able to interact with the simulator via the ‘viewer controls’. Typically, to begin a simulation the user selects the ‘Mode’ via a drop-down option box. The mode gives the user the option to specify the type of input message and output message. Options presented are: Analog→ Analog , Analog→ Digital, Digital→ Analog, and Digital→ Digital. Based on the option selected in the mode drop down menu, the viewer control and layout is reconfigured automatically. For example, in figure 1 Analog→ Analog was selected in the mode box, while in figure 4 Digital→ Digital was selected. Note that the layout are quite different and only allow parameters to be inputted that are relevant to that particular mode. The modulation technique can be selected in the last viewer control box. Note that the corresponding waveforms for the message, carrier and modulated signal are displayed to the right (see figure 1). These waveforms, although ‘frozen’ in time, automatically adjust each time the value of the parameters changes.

## Implementation

The final version of the software simulator was written using JavaScript. The two prior versions used MATLAB for one and LABVIEW for the other. JavaScript was used because it is portable and accessible, that is, all that is needed to run the software simulator program is a modern web browser. The simulator was created by: (i) writing the codes that implement the underlying mathematical equations and communications operations for various analog and digital modulation techniques, (ii) writing the codes to visually display the data or corresponding signal waveforms for the modulation process, and iii) allowing the end-user to interact with the simulator via a graphical user interface. To further explain, consider the amplitude modulation process. This process can be mathematical represented by the following equations.

For a sinusoidal message signal:

$$m(t) = A_m \cos(2\pi f_m t) \quad (1)$$

Carrier Signal:

$$A_c \cos(2\pi f_c t) \quad (2)$$

$$\begin{aligned} \text{Modulated Signal: } S_{AM}(t) &= [A_c + A_m \cos(2\pi f_m t)] \cos(2\pi f_c t) \\ &= A_c [1 + k \cos(2\pi f_m t)] \cos(2\pi f_c t) \end{aligned} \quad (3)$$

where,  $A_m$  and  $A_c$  represent the amplitude of the message signal and carrier signal, respectively;  $f_m$  and  $f_c$  represent the frequency in Hertz of the message signal and carrier signal, respectively;  $t$  represents time, in seconds, and  $k$  is a constant.



These equations are written in JavaScript such that the end-user is able to modify the parameters of the equations via a graphical user interface. The mathematical equations for the aforementioned waveform along with the corresponding plots would also be displayed (see Figure 1). The simulator behaves in a dynamic manner allowing the end-user to modify the values, such as the frequency of the message or carrier signal, and immediately see the corresponding effect on the modulated signal waveform.

### Free Download Available

The simulator along with additional information is available for download at <http://www.engr.siu.edu/techproject>. Instruction is provided at the aforementioned URL to guide in the download and installation process.

### Survey Results and Discussion

A survey was conducted with each year group of students. The primary purpose of the survey was to determine students' attitude towards the simulator. The survey was also used to assess if the objective of the project was met from the students' perspective. The same survey was conducted 3 separate times with two different year group of students. The first two times were to the same group of students. It was conducted initially mid semester (after 7 weeks) and again at the end of the semester. The next year it was conducted for the third time. This was done at the end of the semester with the second group of students. Each time the survey was conducted the results were shared with the developers so that they could use the students' input to improve the simulator. The Likert scaling was used for most of the responses in the survey. Table 1 below summarizes the result of the last time students evaluated the simulator. The total respondents to the survey presented is 18. However, overall survey respondents was 35 over the two year period (2 separate year groups).

**Table 1. Summary of Survey Responses**

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The simulation software layout (interface) is too crowded	0	11.1	5.6	16.7	66.7
2. The simulation software is user friendly	72.2	22.2	5.6	0	0
3. This software is a helpful learning tool for telecommunication fundamentals	61.1	27.8	5.6	5.6	0
4. I would recommend this software to a communication student	55.6	22.2	11.1	11.1	0
5. I would recommend this software to a communication instructor	27.8	55.6	11.1	5.6	0

A few open-ended questions were also included in the survey. These are listed below.

1. Please list any improvements that you think would make the software more user-friendly or a better teaching and learning tool.
2. Please list any important concepts that you think should be included in this simulation.
3. Are there any concepts that should be omitted?

**Table 2. Overall Rating**

Question	Overall, how do you rate this software?
Terrible if not worse	0
Bad	0
OK	33.3
Very Good	11.1
Awesome	55.6%

The results indicated that 94.4% of the students thought that the simulator was user-friendly. 88.9% of the students believe that the simulator was a helpful tool for learning telecommunication fundamentals. A majority of the students felt strongly enough about the utility of the software simulator to the extent that they would recommend it to fellow students and even to instructors. 100% of the survey respondent rated the simulator as either okay, very good or awesome. The tool needs a little refinement and a comprehensive evaluation from professors who teach introductory courses in communication systems. However, the approach using students input as consultants and utilizing their programming skill was very well received and resulted in a fairly satisfactory product. It must be noted that two telecommunication instructors, including one not related to the project, found the simulator to be useful and have utilized it in their classroom to demonstrate, in a visual way, the signal processing stages in analog and digital modulation techniques.

## Conclusion

In this paper, a novel software educational tool, the EET Communication Simulator was presented. The simulator was evaluated at several times during the development process. Survey results indicate that the project has met its objective by creating a simulator that is a pedagogically effective tool from both the students' and instructor's perspective. Future work will include additional features and a refining of the user interface.

## Acknowledgement

This project would not have been possible without the invaluable contributions from the following former and current students: Sean Martin, Alexander McCandless, Ridge Finn, Nicholas Woyak, and Karthik Pendyala.

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