# BROWSER-BASED SIMULATOR FOR CODING AND MODULATION TECHNIQUES

Engr. Joe Arthur R. Agustin[a], Engr.Jondy Paul C. Catalon[b], Ian Daryll M. Ednave[b], Gabriel Lyko C. Eduria[b], Allen Getty Q. Liquigan[b], Engr. Roilo Ardan A. Majarucon[b], Poliyester P. Rivera[b], Jharyl B. Palapal[b], Shiela May N. Rosete[b], Clariza F. Tougan[b]

[a]Saint Louis University, Baguio City
[b]Saint Louis University, Baguio City

*jragustin@slu.edu.ph

Highlights:

- The study involved the development of a simulator of coding and modulation processes and it is intended as a learning and teaching tool for a digital communications course.
- The simulator includes character coding , pulse code modulation, line coding, and digital modulation.
- The evaluators of the simulator suggested its use in teaching digital communications.
- The simulator is easy-to-use and is available for online evaluation at: https:/www.camtes.digital.

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## Abstract

Digitalization has made life better by enhancing communication, education, public services, and health. The rapid growth in applications of digital communication systems resulted in an increase in the demand for technically-trained manpower. As a result, courses in digital communications are offered in the undergraduate level of Electronics Engineering (ECE) and Information and Communications Technology (ICT) programs. However, understanding digital communication principles and processes is difficult. Several universities have developed their own simulators making use of commercial software such as Matlab and Labview to be used as teaching aid for instructors and learning tool for students. The primary objective of the study is the development of a Browser- Based Coding and Modulation Techniques Simulator (CaMTeS) which is free and easy-to-use. The concepts and processes included in the simulator were based on those prescribed in the CHED CMO for ECE programs and course syllabi for Coding and Modulation Techniques. The simulator includes simulations on character coding, pulse code modulation, line coding, and digital modulation. The simulator was developed using HTML5, CSS, and Javascript and it can be run on common browsers like Google Chrome, Firefox Mozilla, and Microsoft Edge. The simulator was evaluated on functionality and usability by faculty members who have taught coding and modulation techniques or similar courses. The overall impression of the evaluators indicated that the simulator is an effective learning and teaching tool and recommended its use in Coding and Modulation Techniques courses.

**Key Words:** Browser-Based Simulator; Character Coding; Digital Modulation; Line Coding; Pulse Code Modulation

## 1. Introduction

Digitalization has revolutionized people's way of communicating and allowed people to stay connected. It opened new ways of virtual and distance learning during this time of pandemic. It became the primary means for personal communication and also for communications in the industry, business, education, and entertainment sectors (Spacey, 2020). It also includes email, phone calls, video conferencing, SMS, and web chats. The conduct of transactions in business and banking, rely on digital communications to provide their means of information exchange as well.

The expansion of the applications of digital communications resulted in a great demand for technically trained personnel who are knowledgeable and skilled to operate these communication systems. It created a need for engineers who are capable of designing and implementing digital communication systems. To provide the needed pool of technical manpower, courses on digital communications are taught in undergraduate and graduate levels of Electronics Engineering (EcE) and Information technology (IT) programs to prepare students for employment in the communications industry.

In the Philippines, the inclusion of a course on digital communications in the Electronics Engineering (EcE) degree program is prescribed by the Commission on Higher Education (CHED) in its Memorandum Order No. 101 (CMO No. 101) series of 2017. The Memorandum Order promulgates the policies and standards for the degree Bachelor of Science in Electronics Engineering (BSEcE) and mandates a curriculum with the course Communications 2: Modulation and Coding Techniques which is to be conducted as a 3-unit lecture class and 1-unit laboratory class. The course outline for the lecture class stipulates topics such as (a) Introduction to Digital Communications Systems, (b) Digital Transmission, (c) Pulse Code Modulation, (d) Digital Modulation, (e) Error Control, and others. For the laboratory class, training modules or their equivalent are required for performing experiments in Pulse Amplitude Modulation (PAM), Noise, Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Pulse Code Modulation (PCM), and Error Control. It is expected that upon completion of the course, the students will be able to conceptualize, analyze, and design digital communication systems.

A typical digital communications course usually begins with the introduction of a digital communication systems with the aid of block diagrams that represent the major processes. The functions of each block are described to provide an overview of the end-to-end system operation. For the rest of the semester, the signals and processes are explained using mathematical models, and the system's performance is analyzed by performing mathematical computations. To avoid performing complex computations in the classes, simplified examples are mostly discussed. The effects of varying signal characteristics and adjusting system parameters are rarely presented because the mathematical models become complicated and the computations involved become time-consuming.

Studying the concepts of digital communications is a challenging task. Many students experience difficulty and fail to understand mathematical concepts related to signals and processes. Students become too absorbed in the computations and fail to visualize the signals and processes that the computations are supposed to show and demonstrate. According to Professor Michael Rice (2009) of Brigham Young University of Utah, "students must understand the principles of digital communication before they work on actual systems. When digital communication coursework is nothing but theory, students leave their classes swimming in information and unsure how all the pieces fit together. They know how to manipulate equations but have no idea how a real system works".

Students benefit significantly when computers are included in the learning process. Interactive simulators are commonly used to help students grasp complex technologies. Simulators can be programmed to make computations easier and they can be set up to display graphs that show how signals and systems behave.

Several universities have adopted the use of computer simulators for teaching digital communications and some even developed their own simulators. At Northern Illinois University, USA, Abul K. M. Azad developed a Matlab-based simulator for digital modulation techniques. A simulator of similar nature was developed by Gohokar at the Royal Melbourne Institute of Technology, Melbourne. In the Philippines, De La Salle University researchers developed laboratory experiments to be performed using LabVIEW. These simulators developed using proprietary software such as Matlab, Simulink, and Labview require the installation of the same software to be able to use the simulators. Thus, users are limited to those who can afford the software. In the study "Computer-Based Simulator for Digital Communications" faculty members of Saint Louis University developed a simulator for the source coding and channel coding processes using the freeware Scilab which allow students to use the simulator without the need for proprietary software (Agustin & Agustin, 2016).

Simulators will benefit more if they are developed as browser-based simulators. Browser-based simulators are developed to run on web browsers such as Google Chrome, Firefox Mozilla, and Microsoft Edge, commonly obtained as freeware or automatically installed with the operating system. The advantage of a simulator that runs in a browser is that it is directly executable on the user or client browser. Unlike proprietary software, browser-based simulators do not put a heavy load on the computer system. Thus, it can operate on slower personal computers and entirely offline. According to Schroeder (2014), a browser-based program can run on any browser, and there is no need to create separate versions of the program for different devices.

Based on the preceding discussions, the researchers believed that a properly designed interactive and user-friendly simulator for digital communications processes is a tool for improving the learning experience of students as well as the teaching methods of instructors. Hence, the researchers developed a browser-based computer simulator for the coding and modulation techniques of digital communication systems with the primary objective of providing a free and easy-to-use simulator for students and instructors of digital communications courses.

## 2. Methods

The study employed descriptive research and applied research. The researchers used descriptive research in understanding the concepts and processes of coding and modulation techniques. It was also used in learning simulation algorithms and programming techniques that apply to the development of the simulator

The researchers adopted the prototyping methodology called Rapid Application Development (RAD). With RAD methodology, the development of the simulator underwent iterations that included three phases: (1) Analysis, (2) Design, and (3) Implementation and Testing. The three stages were done cyclically until the simulator was satisfactorily completed.

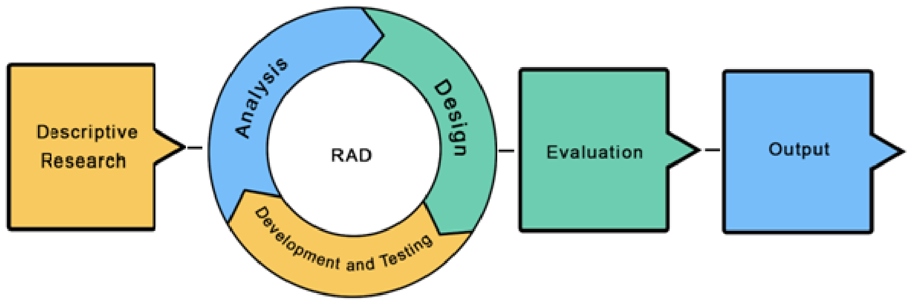


Figure 1. Phases of the Project Development.

In the first RAD cycle, the simulator was designed based on coding and modulation processes to be simulated and programming algorithms were conceptualized. An initial simulation program was constructed and tested. When test results were unsatisfactory, the design and program were evaluated to determine the causes and the design and/or program were consequently modified. When the test results were satisfactory, additional features were added to enhance the project. The analysis step included identifying the to-be-simulated processes, constructing mathematical models, and designing the GUI layout. The GUI of the simulator was designed to make it simple to utilize user-defined inputs, track process flow, and display simulation results.

During the design phase, a flowchart was created to depict the simulation program's functioning. The flowchart divided the simulation program into independent sections. Each program module accepts and returns outputs. Test data for the modules and simulator were also prepared. Simulation results were validated using input parameters and expected results. Implementation and testing included designing, running, and testing simulator program codes with test data. Before integrating them into the simulator, the modules were programmed and tested individually.

To gather data, the researchers utilized primary and secondary tools. In particular:

1. To determine the concepts that are included in the simulations, the researchers reviewed pertinent provisions of CHED Memorandum Order 101 series of 2017, syllabi of lecture and laboratory courses for Modulation and Coding Techniques courses.
2. To determine the appropriate programming algorithms and techniques for the simulator development, the researchers referred to books, journals, and articles available on the internet.
3. To evaluate the simulator, its operation was demonstrated to faculty members who have taught Modulation and Coding Techniques or similar courses. The simulator was also given to them for further exploration of its function and features. The evaluators were then provided an evaluation checklist to indicate their evaluation results. Post-evaluation interview was also conducted with each evaluator to discuss the evaluation results and clarify the recommendations of the evaluators.

## 3. Results and Discussions

### *3.1. Description and Operation of the Simulator*

The Browser-Based Simulator for Coding and Modulation Techniques Simulator (CaMTeS) is a compilation of ten (10) independent sub-simulators for the processes involved in a digital communication system. Each of the ten sub-simulators is complete and executable. The ten sub-simulators are classified into four (4) groups: Character Coding, Pulse Code Modulation (PCM), Line Coding, and Digital

Modulation. There is only one simulator each for Character Coding and Line Coding. The PCM group includes six simulators while the Digital Modulation Group includes three simulators. The groupings of the simulators are as follows:

1. Character Coding Simulator
2. Pulse Code Modulation (PCM)
   - Basic PCM Simulator
   - PCM With Analog Companding Simulator
   - PCM With Digital Companding Simulator
   - Delta PCM Simulator
   - Adaptive Delta PCM Simulator
   - Differential PCM Simulator
3. Line Coding Simulator
4. Digital Modulation
   - Amplitude Shift Keying (ASK) Simulator
   - Frequency Shift Keying (FSK) Simulator
   - Binary Phase Shift Keying (BPSK) Simulator

The Character Coding Simulator can be used to simulate the encoding and decoding of text messages using two common character codes such as ASCII and EBCDIC. The use of parity bits is also demonstrated.

The PCM simulators can be used to simulate the process of encoding analog signals into bits and the decoding of bits to reconstruct the analog signal. The simulators for PCM with companding can be used to demonstrate the improvement in the encoding and reconstruction of low-amplitude analog signals. The simulators for Delta, Adaptive Delta, and Differential PCMs can be used to demonstrate the coding and reconstruction of analog signals using fewer bits.

The Line Coding simulator can be used to generate the waveforms of different line codes. The line codes can be simulated in relation to effect of bandlimited channels on the waveforms of the pulses.

The Digital Modulation Simulators can be used to simulate the modulation and demodulation processes using analog carriers. The three basic forms of digital modulation such as ASK, FSK, and BPSK are included. The simulations include generation of the waveforms of the modulating signal, carrier signal, and demodulated signal.

When the Coding and Modulation Techniques Simulator (CaMTeS) is launched on a browser, the About Us page is displayed. The page contains a brief description of CaMTeS and an introduction of the developers. The About Us page includes a Contact Us button that directs to an email page for contacting the developers and a Simulate button for proceeding to the Main Simulation window.

The Main Simulation window, shown in Figure 2, displays icons for the simulation groups. When the cursor is hovered on a particular icon, a description of the group is displayed. Clicking on an icon launches the simulator page or opens a menu for selecting a simulator in the group. A pull-down menu, shown in Figure 3, is also provided for selecting the simulators or going back to the About Us page.

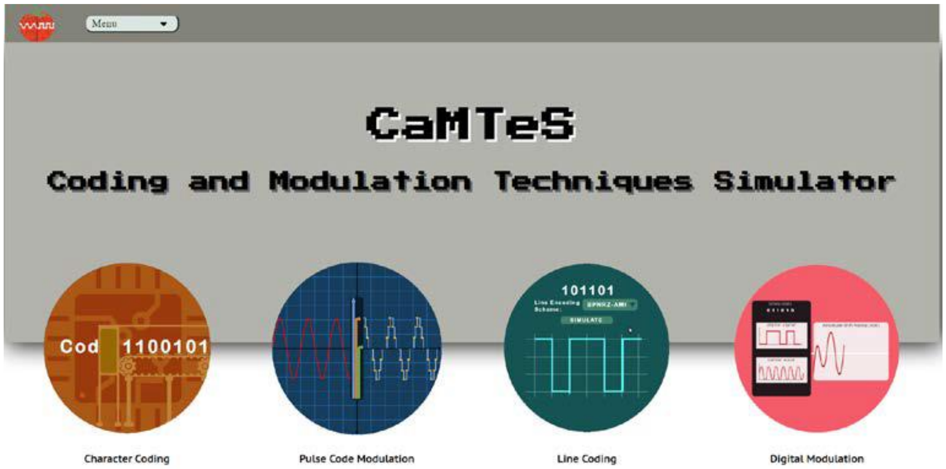


Figure 2. Main Page of CaMTeS.

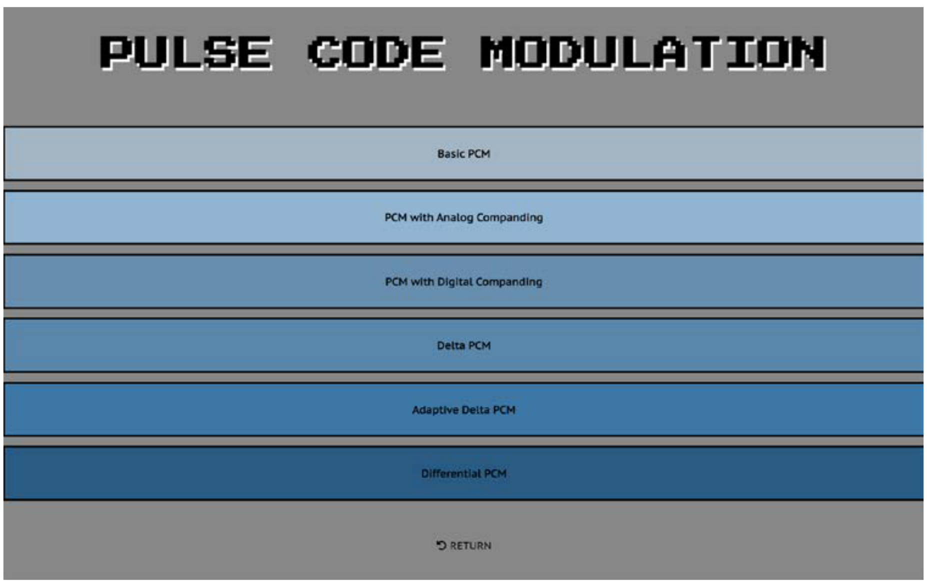


Figure 3. Menu for Selecting a Simulator in the PCM Group.

The Overview page for a certain simulator is displayed when it is selected and launched. A block diagram and a brief description of the simulated system is displayed in the Overview page. An animation of the process flow from the system's input to output is represented in the block diagram. The Overview page has a Simulator tab that takes the user to the simulation page. A simulator's simulation page typically includes the following: (1) a dialog box for setting up simulation parameters, (2) a simulate button for running the simulation with the current parameter settings, (3) a results window for seeing simulation results, and (4) a dialog box for changing graph properties like color, thickness, and background color. The PCM simulators come with a playback box that can play back both the input and output signals.

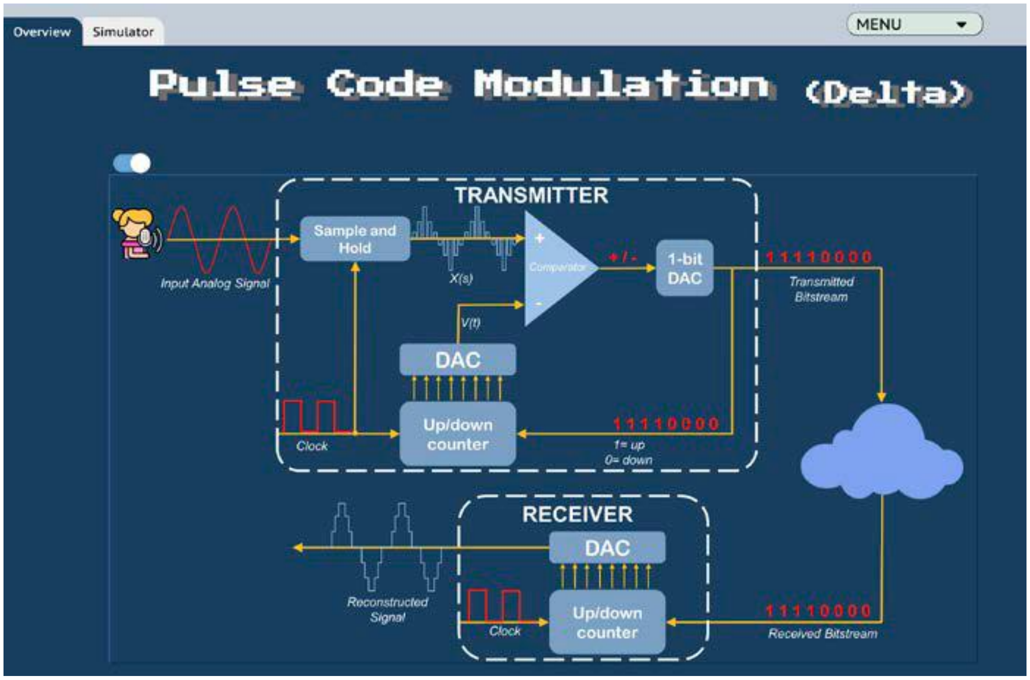


Figure 4. Overview Page of the Delta Pulse Code Modulation Simulator.

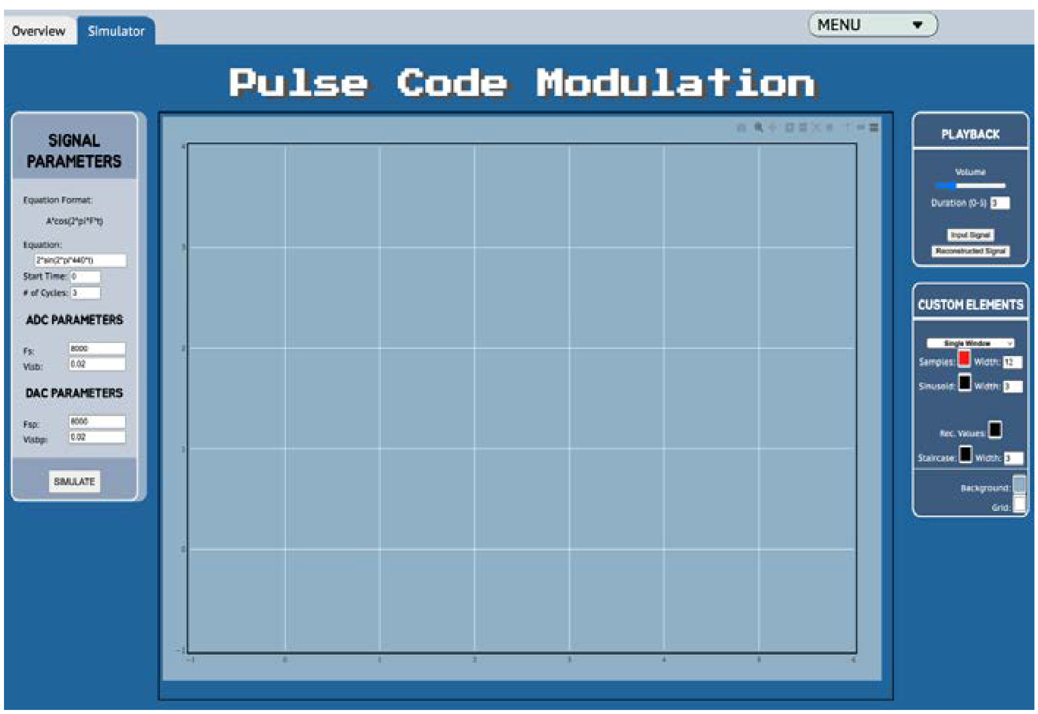


Figure 5. Simulation Page of the Basic PCM Simulator.

The simulation results include bit streams, computed values, and graphs in the time-domain and frequency domain. Bit streams and computed values are generally displayed in table form as shown in Figure 6. For graphical display, multiple graphs may be displayed in a single window or split a window into two sub-windows. Several features for graphical display are available, such as: (1) saving the displayed graph as an image file in .png format, (2) zoom in, (3) zoom out, (4) pan, (5) autoscale, (6) axes reset, (7) spike lines toggle, and (8) data values on hover. The following figures show the manner in which simulation results are displayed in the simulators.

ADC VALUES

| n | Sampling Time | Sampling Values | Quantized Values | PCM Codes |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 10000000 |
| 2 | 0.000125 | 0.6774758 | 0.68 | 10100010 |
| 3 | 0.00025 | 1.274848 | 1.28 | 11000000 |
| 4 | 0.000375 | 1.7214841 | 1.72 | 11010110 |
| 5 | 0.0005 | 1.9645745 | 1.96 | 11100010 |
| 6 | 0.000625 | 1.9753767 | 1.98 | 11100011 |
| 7 | 0.00075 | 1.7526134 | 1.76 | 11011000 |
| 8 | 0.000875 | 1.3226237 | 1.32 | 11000010 |
| 9 | 0.001 | 0.7362491 | 0.74 | 10100101 |
| 10 | 0.001125 | 0.0628215 | 0.06 | 10000011 |
| 11 | 0.00125 | -0.618034 | -0.62 | 00011111 |
| 12 | 0.001375 | -1.2258141 | -1.22 | 00111101 |
| 13 | 0.0015 | -1.6886559 | -1.68 | 01010100 |
| 14 | 0.001625 | -1.9518335 | -1.96 | 01100010 |
| 15 | 0.00175 | -1.9842294 | -1.98 | 01100011 |
| 16 | 0.001875 | -1.782013 | -1.78 | 01011001 |
| 17 | 0.002 | -1.3690942 | -1.36 | 01000100 |
| 18 | 0.002125 | -0.7942958 | -0.8 | 00101000 |
| 19 | 0.00225 | -0.125581 | -0.12 | 00000110 |
| 20 | 0.002375 | 0.5579822 | 0.56 | 10011100 |
| 21 | 0.0025 | 1.1755705 | 1.18 | 10111011 |
| 22 | 0.002625 | 1.6541611 | 1.66 | 11010011 |
| 23 | 0.00275 | 1.9371663 | 1.94 | 11100001 |
| 24 | 0.002875 | 1.9911239 | 2 | 11100100 |
| 25 | 0.003 | 1.8096541 | 1.8 | 11011010 |
| 26 | 0.003125 | 1.4142136 | 1.42 | 11000111 |
| 27 | 0.00325 | 0.8515586 | 0.86 | 10101011 |
| 28 | 0.003375 | 0.1882166 | 0.18 | 10001001 |
| 29 | 0.0035 | -0.4973798 | -0.5 | 00011001 |
| 30 | 0.003625 | -1.1241668 | -1.12 | 00111000 |
| 31 | 0.00375 | -1.618034 | -1.62 | 01010001 |
| 32 | 0.003875 | -1.9205874 | -1.92 | 01100000 |
| 33 | 0.004 | -1.9960535 | -2 | 01100100 |
| 34 | 0.004125 | -1.8355093 | -1.84 | 01011100 |
| 35 | 0.00425 | -1.4579373 | -1.46 | 01001001 |

Figure 6. Computed Values Displayed in Table Form.

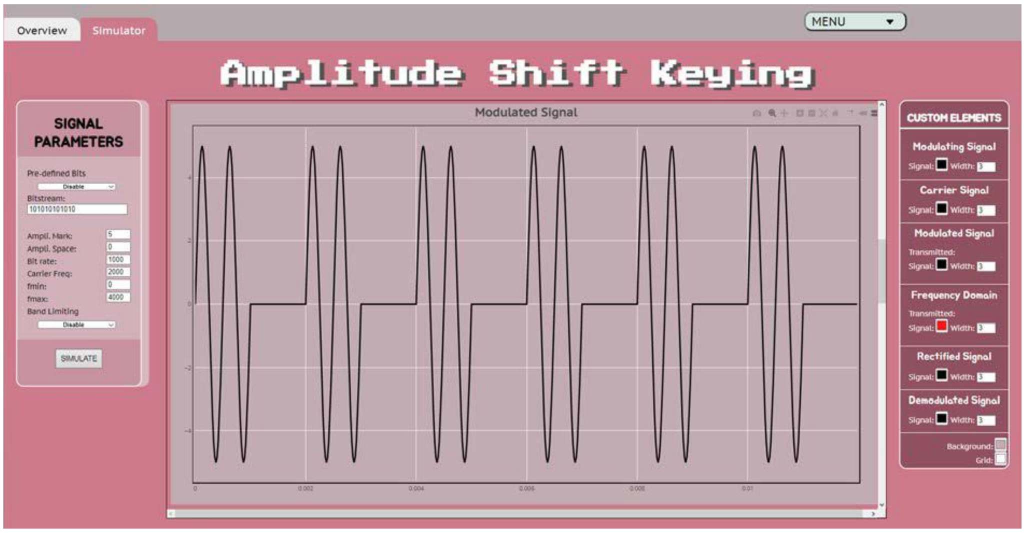


Figure 7. Single Graph Displayed in One Window.

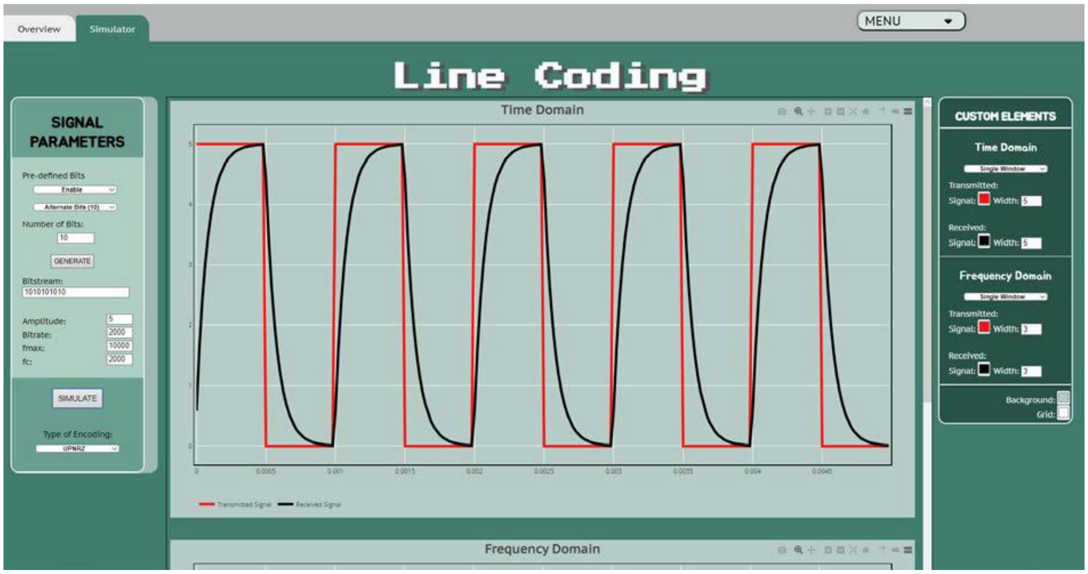


Figure 8. Multiple Graphs Displayed in One Window.

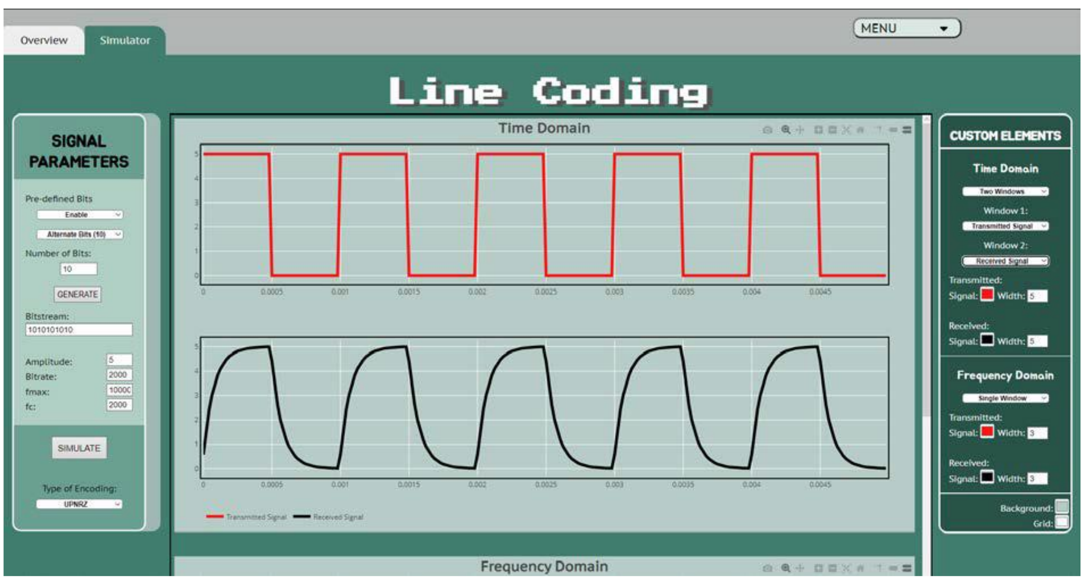


Figure 9. Multiple Graphs Displayed in Separate Sub-Windows.

*3.2 System Requirements*

CaMTeS simulator can run on common browsers that are HTML 5 updated and JavaScript enabled. The simulator is compatible with any screen size or aspect ratio. To ensure smooth operation, the simulator should be run on personal computers with the following recommended minimum software and hardware specifications.

**Software Requirements**

**Operating System:** Windows 10 (32 or 64-bit)

**Browser:** Compatible with HTML 5 language such as Google Chrome, Microsoft Edge (Formerly Internet Explorer), Mozilla Firefox, Opera, and Safari.
**Hardware Requirements**
**CPU:** Processor: Pentium Core
**RAM:** 4GB (Gigabytes)
**Storage:** 100 MB Hard Disk Space
**Display:** SVGA Monitor or higher resolution
**Audio:** 16-bit Audio Card

*3.3. Evaluation of the Browser-Based Simulator for Coding and Modulation Techniques*

The evaluation of the Browser-Based Coding and Modulation Techniques Simulator was done by four (4) Electronics Engineering faculty members who have taught Coding and Modulation Techniques or similar courses. The faculty members were provided with the simulator programs, user manual, and a demonstration video. The video demonstrates the features, use, and operation of the simulator. The evaluators were requested to try the simulator and accomplish an evaluation checklist to indicate their evaluation of the simulation and to provide feedback. The said evaluation checklist was done in order for the simulator to be validated in relation to the applicable attributes of a simulator according to ISO 9126. After the evaluators finished the evaluation checklist, the researchers conducted post-evaluation interviews to provide a venue for the evaluators to clarify their concerns regarding the simulator, user manual, and the evaluation checklist. The interview also provided a venue for the researchers to solicit recommendations for improving the simulator from the evaluators.

There were three sections to the evaluation checklist. The purpose of the first section was to test the simulator's functionality. In the second section, the usability of the simulator was confirmed, and in the third section, the overall opinion of the simulator as a learning and teaching tool was determined. The checklist listed the simulator's desired attributes and for each attribute the respondents were instructed to respond with a YES if they believe the attribute is present in the simulators and a NO if they do not believe the attribute is present in the simulators. The following pages include the tabulations of the results.

*3.3.1. Functionality*

This section was intended to determine if the simulator serves the purpose of enhancing the teaching and learning process in Coding and Modulation Techniques.

Table 1. Evaluation Results for Functionality.

| ATTRIBUTES | YES | NO |
|---|---|---|
| The simulator includes simulations that cover most of the topics in Coding and Modulation Techniques. | 4 | |
| The simulator provides appropriate visualization that enhances understanding of concepts of coding and modulation techniques. | 4 | |

| | | |
|---|---|---|
| The simulation results demonstrate correctly the concepts of coding and modulation techniques. | 4 | |
| The simulator aids in recalling and applying concepts of coding and modulation techniques. | 4 | |
| The simulator facilitates learning and understanding of the effects of varying parameters in coding and modulation techniques. | 4 | |

*3.3.2 Usability*

This section was intended to determine if the simulator is user-friendly, easy to use, and presents the simulation results in an appropriate manner.

Table 2. Evaluation Results for Usability.

| ATTRIBUTES | YES | NO |
|---|---|---|
| The simulator is easy to install. | 4 | |
| The user manual provides sufficient information on how to use the simulator. | 4 | |
| The procedures and instructions in the user manual are clear and easy to follow. | 4 | |
| The onscreen texts are easily readable. | 3 | 1 |
| The graphs are displayed in a manner that effectively conveys information and concepts visually. | 4 | |
| The buttons and dialog boxes operate properly. | 3 | 1 |
| The simulator is easy to learn. | 4 | |
| The simulator is easy to navigate and easy to learn. | 4 | |
| The simulator allows the simulation parameters to be changed easily. | 4 | |
| The simulator is able to manage incorrect simulation parameters (i.e. provides notification for out-of-range parameter values and allows users to correct incorrect parameters to reset the simulations). | 3 | 1 |

*3.3.3. Overall Impression*

This section intends to determine the overall impression of the respondent of the simulator as a learning and teaching tool for coding and modulation techniques.

Table 3. Evaluation Results for Overall Impression.

| QUESTIONS | YES | NO |
|---|---|---|
| Do you think that the simulator will be an effective learning aid for students in coding and modulation techniques? | 4 | |
| Do you think that the simulator will be an effective teaching aid for instructors in coding and modulation techniques? | 4 | |
| Would you recommend the use of the simulator as learning and teaching aid in coding and modulation techniques? | 4 | |

The evaluators were satisfied with the Browser-Based Simulator's functionality based on the evaluation findings. The interviewers remarked that the simulator covers most coding and modulation subjects. The simulator also helps apply principles and learn about the results of varying parameters in coding and modulation. All evaluators commended the simulator's usefulness in providing visualization of coding and modulation concepts..

Several evaluators said the simulation was straightforward to use and presentable. In one of the post-evaluation interviews, an evaluator advised making the background color lighter which the developers incorporated in the revised simulator. Overall, the evaluators said the simulator is a good tool for students and teachers to learn coding and modulation.

## 4. Conclusions

Based from the results, and finding, the researchers were able to conclude the following:

1. The Coding and Modulation Techniques processes and concepts included in the simulator are Character Coding, Pulse Code Modulation, Line Coding, and Digital Modulation.
2. The simulator was developed using JavaScript, CSS, and HTML5 and integrated into a single simulator using Visual Studio Code to be used on computers with minimal hardware specifications.
3. The design and development of the project considered the inclusion of attributes on functionality and usability which are prescribed characteristics of software quality in ISO 9126.
4. The evaluation results from four (4) faculty members indicated that the attributes are perceived to be present in the simulator.
5. Based on the evaluation checklist and post-evaluation interview, the overall impression of the evaluators indicated that the simulator is a good learning and teaching tool for students and instructors and recommended its use in Coding and Modulation Techniques courses.

## References

Africa, A. D. M., Maglalang, M. J. F., Meer, E. A., & Robin, M. P. (2016, October). Development Of The Digital Communications Laboratory Experiments Using Labview Software With Data Acquisition Functions. Retrieved November 26, 2021, from https://lpulaguna.edu.ph/wp-content/uploads/2017/03/Development-of-the-Digital-Communications-Laboratory-Experiments-Using-Labview-Software-with-Data-Acquisition-Functions.pdf.
Adamo, J. M. (1980) Fuzzy decision trees. Fuzzy Sets and Systems, Vol. 8, No. 3, 207-220.

Agustin, Z.L. & Agustin, J.R. (2016). Computer-Based Simulator for Digital Communications. Proceedings of the ICEE-PHIL 2016, pp. 132-137. ISSN# 2467-7507

Azad, A. (2015, March 10). Teaching of digital modulation techniques using a simulation environment. ASEE PEER Document Repository. Retrieved November 25, 2021, from https://peer.asee.org/teaching-of-digital-modulation-techniques-using-a-simulation-environment.

Balachandran, Rabuya, Shinde, Takalkar, & A. L. S. A. (n.d.). Simulation steps and criteria. *Uh.Edu*. Retrieved November 19, 2020, from https://uh.edu/%7Elcr3600/simulation/steps.html

ISO/IEC 9126 in software engineering. GeeksforGeeks. (2021, October 29). Retrieved November 25, 2021, from https://www.geeksforgeeks.org/iso-iec-9126-in-software-engineering/.

Mergedfile - ched. (n.d.). Retrieved November 25, 2021, from https://ched.gov.ph/wp-content/uploads/2018/08/CMO-101-s.-2017-BS-Electronics-Engineering.pdf.

Rice, M. (2009). Teaching Digital Communications Theory with Simulink at Brigham Young University. MATLAB Digest. Retrieved November 29, 2021 from https://www.mathworks.com/company/newsletters/ articles/teaching-digital-communication-theory-with-simulink-at-brigham-young-university.html

Spacey, J. (2020, June 17). 18 Examples of Digital Communication. Simplicable. https://simplicable.com/en/digital-communication

Schroeder, D. (2014, July 27). Creating Interactive Web Simulations Using HTML5 and JavaScript. Introduction. https://physics.weber.edu/schroeder/html5/intro.html