Software Lab Implementation of Amplitude Modulation during COVID-19 Isolation

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Abstract

ECEN 325 Communications Systems class in Electrical and Computer Engineering Department in the University of Nebraska is four credit hour class with a three-hour lecture and three-hour lab. ECEN 325 is a junior class. The laboratory class used to consist of hardware labs. However, the laboratory class went through significant changes during the COVID-19 isolation period. Most of labs were converted to software labs so that students could perform the laboratory in isolated environment to enhance the students' safety. We focus on amplitude modulation (AM) in this paper. We present the hardware AM lab and software AM lab each with the student performance evaluation. Students' exposure to contemporary communication system software simulation tools such as System Vue will certainly help prepare STEM (science, technology, engineering, and math) graduates for the jobs of today and tomorrow.

Keywords

Hardware and software lab, amplitude modulation, Electrical and Computer Engineering, COVID-19.

1. Introduction

Amplitude modulation (AM) is a modulation technique employed in communication systems for transmitting information using a radio frequency carrier [1]. AM is employed in radio broadcasting systems. AM modifies the amplitude of the carrier to transmit information [2]. AM, frequency modulation (FM) and phase modulation (PM) represent analog communication modulation techniques [3]. Demodulation is a receiver technique to process the received signal and recover the information from the modified carrier signal. Until 2020, all laboratories of ECEN 325 Communications Systems, one of the Electrical and Computer Engineering classes, , had been taught with hardware implementation lab [4]. However, to comply with the COVID-19 isolation policy, all the lab classes were converted into software simulation to make it possible for students to perform the lab in isolated environments. This paper focuses on AM, one of the key laboratory classes of ECEN 325 Communication Systems which is a junior class in the department of Electrical and Computer Engineering at the University of Nebraska. The lab's student performance evaluation is presented in the timeline of before and after COVID-19. ECEN 325 AM lab from 2018 to 2020 is presented with traditional hardware implementation of the lab. On the other hand, the years of 2021 – 2022 represent the AM software simulation lab using System Vue. Students' exposure to contemporary communication system software simulation tools such as System Vue will certainly help prepare STEM (science, technology, engineering, and math) graduates for the jobs of today and tomorrow [5].

2. Hardware Implementation of AM

The hardware implementation of amplitude modulator is shown in Figure 1 with a breadboard and the electronic components such as operational amplifier, capacitors, and resistors. After the power is supplied to the circuit, the function generator is connected to supply the 50 kHz carrier. The 200 Hz information signal is provided from one of the channels of the function generator. After observing the AM signal in the oscilloscope, the spectrum analyzer is connected to the circuits to carefully observe the power spectrum of the AM signal as shown in Figure 2.

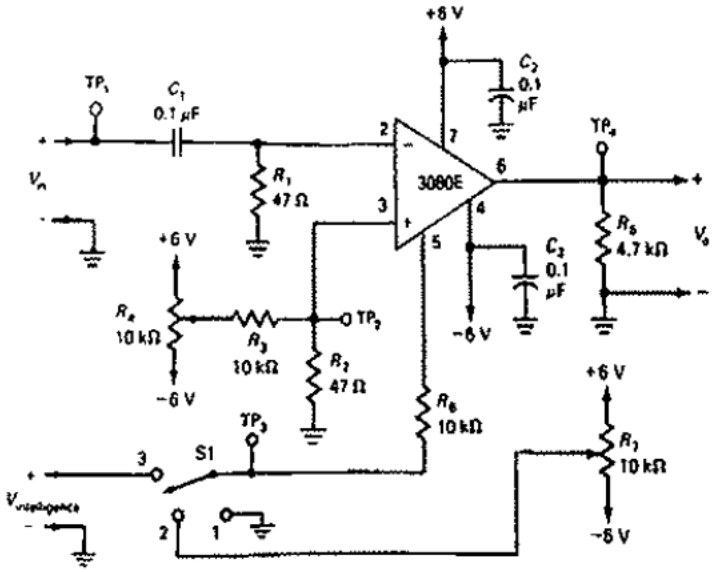

Figure 1. Amplitude Modulator; hardware lab.

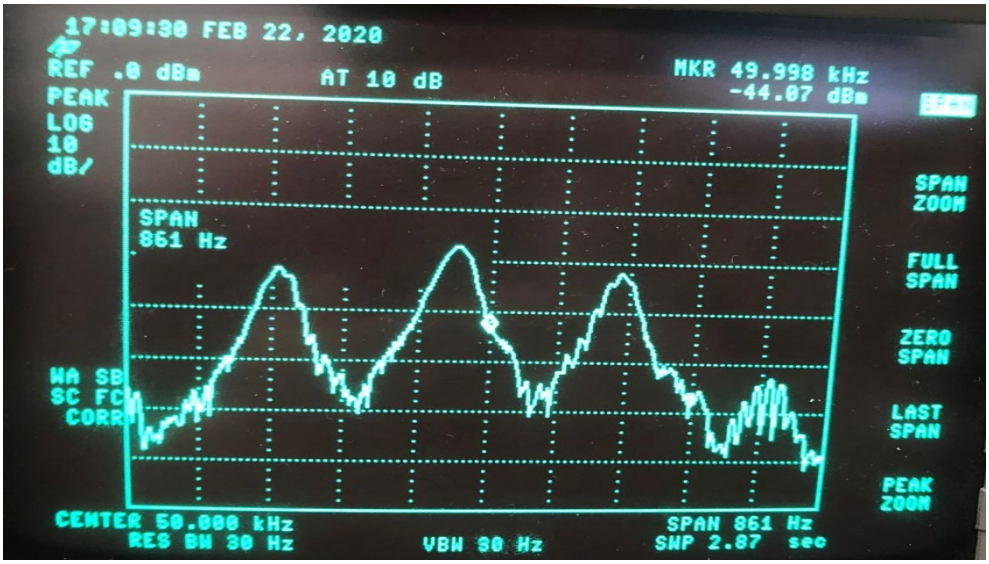

Figure 2. Power spectrum of AM; spectrum analyzer.

3. Software Implementation of AM

The software implementation of AM is shown in Figure 3 using System Vue. System Vue is a system-level design that allows development of design, testing and verification through software simulation tool. Modulation index indicates the ratio of the peak amplitude of the message signal to the carrier amplitude. Power efficiency is the ratio of the message signal power in the sideband to the total power. Power efficiency is the crucial indicator to understanding the efficiency of the AM system. For this purpose, the first step is to create the schematic diagram of the AM shown in Figure 3. Once the design phase is completed, proper system parameters are chosen such as message signal amplitude and frequency, and carrier amplitude. Next step is to click Design Analysis and set the simulation stop time. S1 is the signal generator to generate a message signal and S2 is the signal generator to produce the carrier signal. S3 and S4 are the time domain output for message signal and AM signal, respectively. After the system is run, students can observe both time domain output and spectral outcome. Spectral outcome can be observed in S5.

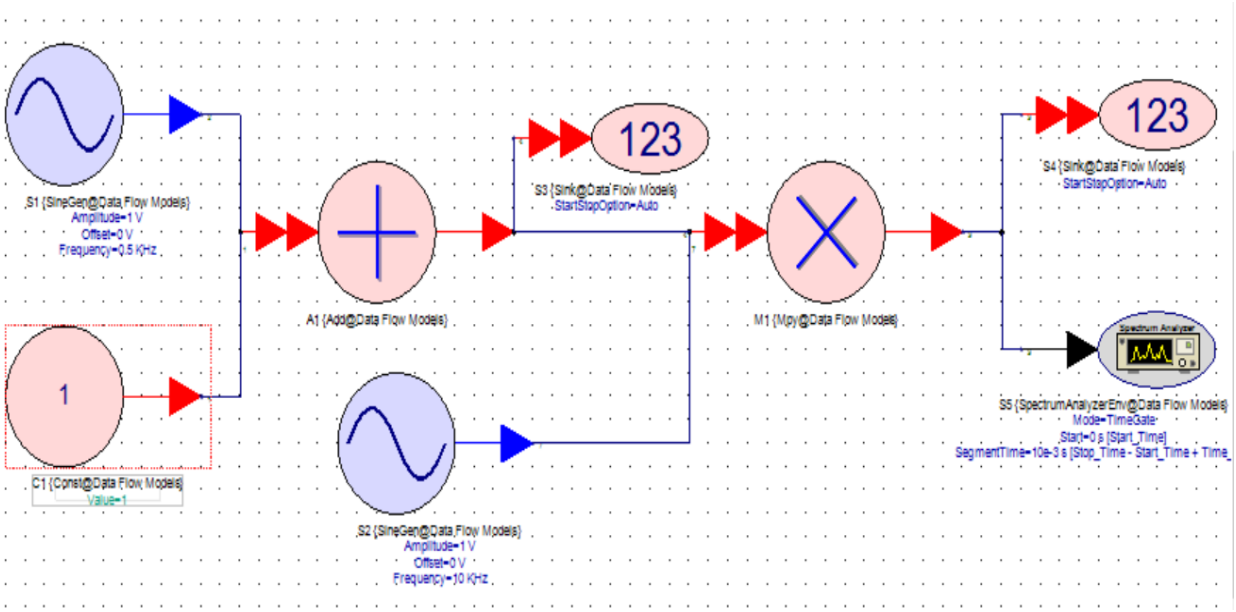

Figure 3. Amplitude Modulator using System Vue.

The power spectrum of AM can be observed in Figure 4. The carrier frequency is 10 KHz with 10 dBm (10 mW) carrier power. The sideband can be seen at 9.5 KHz and 10.5 KHz. Since the constant C1 is the unity, the system has a 100% modulation index. The system is tone modulation and the power efficiency is 1/3. Compared to Figure 2 for the hardware implementation lab, the sideband looks simple presentation without any spectral spread around the carrier, only two tones for the message signal. However, the frequency resolution in the horizontal axis can be controlled like Figure 2. In any case, in terms of modulation index or power efficiency, both hardware and software implementations of AM display a similar result to convey the essential concept of AM with sufficient accuracy for an educational purpose.

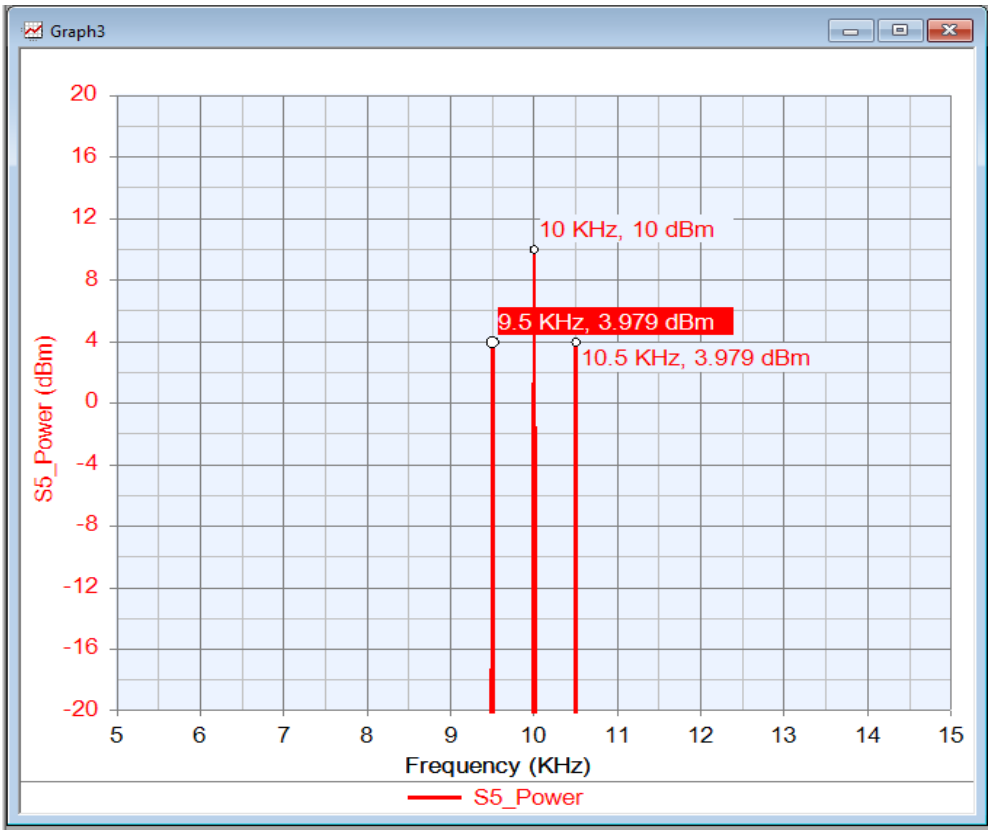

Figure 4. Power spectrum of AM using System Vue.

4. Student Performance Evaluation

Remember that hardware lab was performed in 2018, 2019, and 2020. The average and its distribution of students' grade of AM lab are shown in Figure 5. A similar average score of 97.66, 96.25, and 95.43 for 2018, 2019, and 2020, respectively, are shown in the figure. The grade is evaluated out of 100. Hence, the students' performance is highly scored. The result is compared to the total grade of students for all ECEN 325 laboratory classes. The averages of the total grades are 93.56, 94.07, and 88.71 for 2018, 2019, and 2020, respectively, as shown in Figure 6. As a result, the complexity of the hardware AM lab can be considered equivalent to other labs of ECEN 325 class. However, in 2020, there is some deviation between AM lab and other labs since the average of AM lab is 95.43 while the average of all ECEN 325 lab classes is only 88.71. This is because some students did not turn in all lab reports, and the total grade became lower. It is clear from Figure 6 that the number of students below 70 is larger than other years such as 2018 or 2019. In fact, there are no students who received a total grade below 70 in 2019. Figure 5 is plotted grade (xlabel) versus the number of students (ylabel) except the last one in the right bottom corner. Figure 6 is plotted students (xlabel) versus grade (ylabel) except the last one in the right bottom corner. The last ones in Figures 5 and 6 are plotted student (xlabel) versus grade (ylabel) in ascending order. The labels are explained in the context to present the figures more clearly in the limited space.

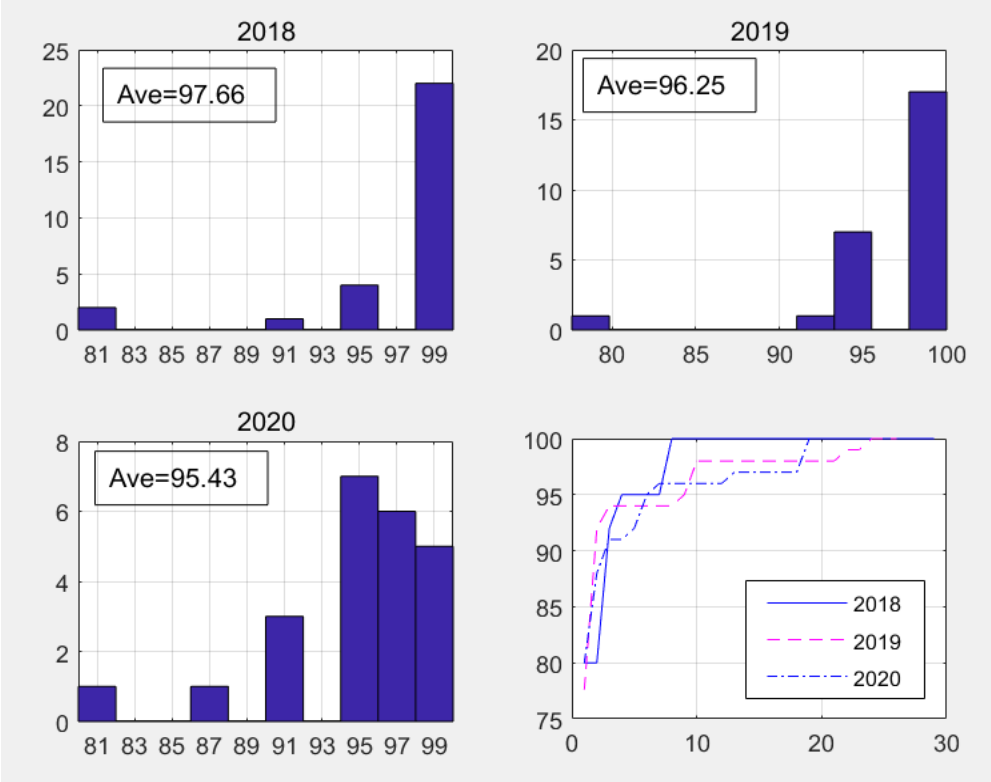

Figure 5: Hardware lab of AM; histogram of grade distribution; 2018 – 2020; xlabel (grade), ylabel (number of students).

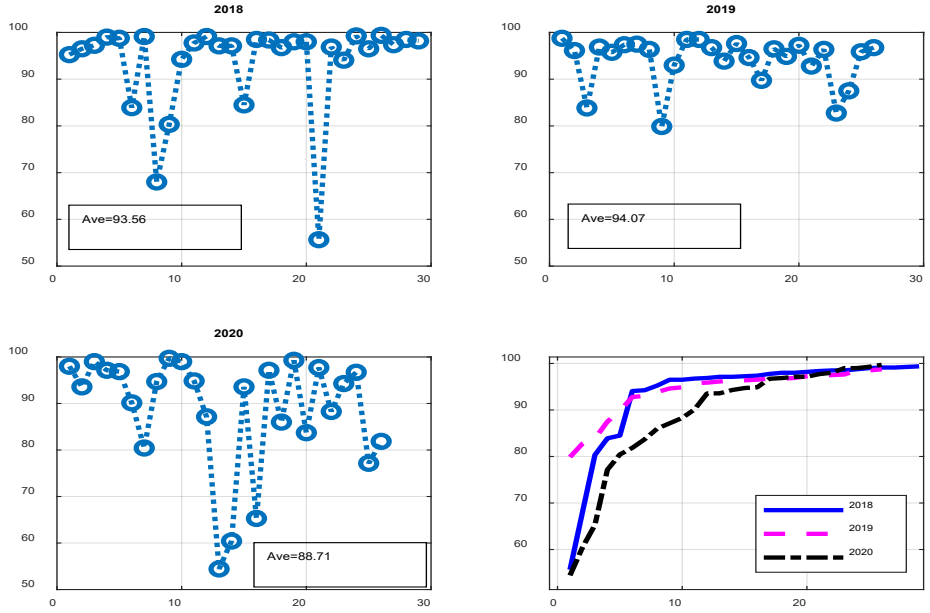

Figure 6: Hardware labs; total lab grade; 2018 – 2020; normalized; xlabel (students), ylabel (grade).

Let us consider the software labs during 2021 – 2023. The software lab design and simulation were executed using System Vue of KEYSIGHT. The average of software AM lab is 89.89, 89.43, and 90 in 2021, 2022 and 2023, respectively, as shown in Figure 7. The average grade of student's software simulation of AM lab is a little lower than that of the corresponding hardware lab. The AM lab grade can be compared to the total ECEN 325 labs for each year. We can see that the average of 85.72, 86.34, and 83.91 in Figure 8. AM lab grade is shown to be a little higher than the total lab grade. The same reason can be applied to the result. Since a couple of students did not turn in some of the lab reports, the total grade became lower. In fact, we also notice that 2023 total lab grade is lowest of the three years of 2021 – 2023. This is because one student was below 40 as shown in Figure 8. We verified that the student did not submit two lab reports. The distribution of AM lab software simulation grade is compact around 90 in 2023, while the distribution of of AM lab is widely spread around 50 to 100 in 2022, although their averages are close each other, that are, 89.43 and 90 in 2022 and 2023, respectively. Figure 7 is plotted grade (xlabel) versus the number of students (ylabel) except the last one in the right bottom corner. Figure 8 is plotted students (xlabel) versus grade (ylabel) except the last one in the right bottom corner. The last ones in Figures 7 and 8 are plotted student (xlabel) versus grade (ylabel) in ascending order. The labels are explained in the context to present the figures more clearly in the limited space.

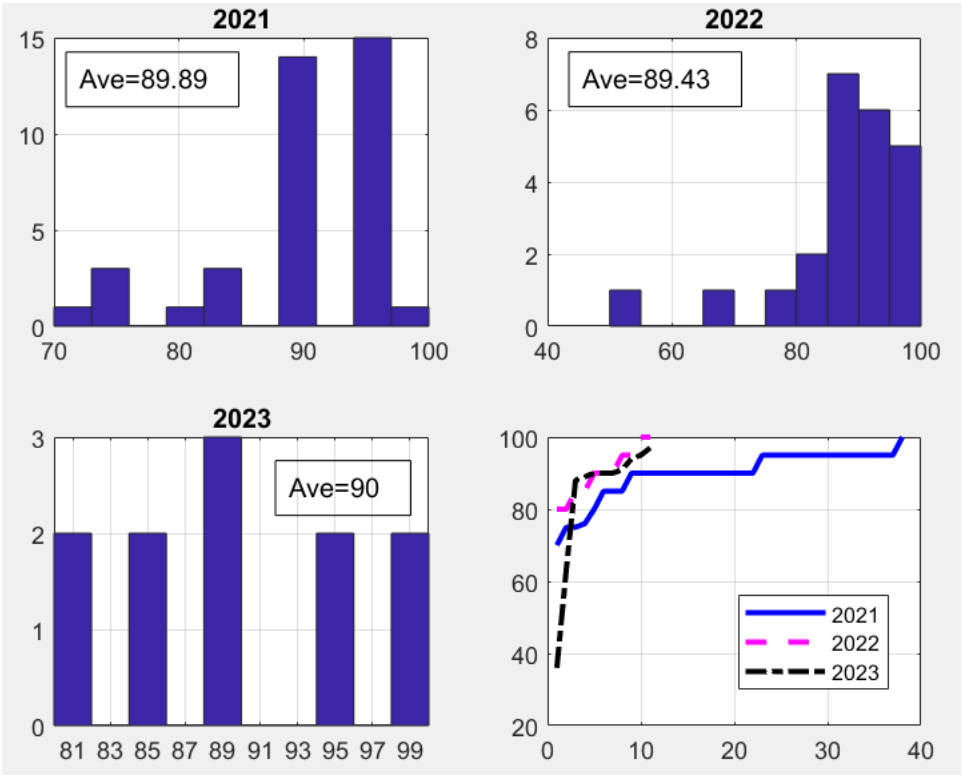

Figure 7: Software lab of AM; histogram of grade distribution; 2021 – 2023; xlabel (grade), ylabel (number of students).

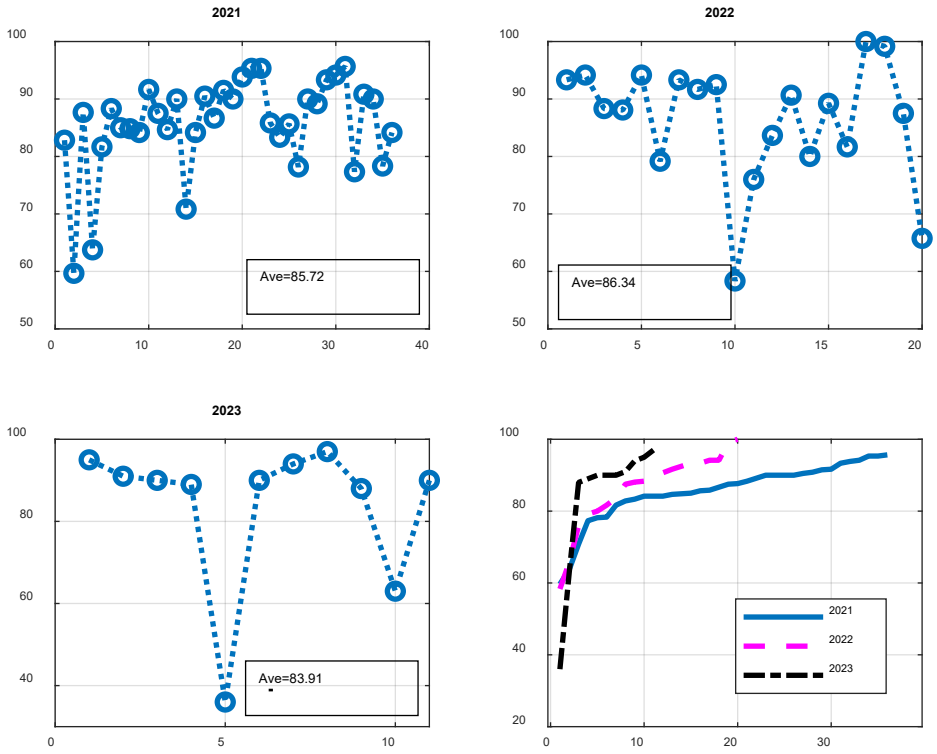

Figure 8: Software labs; total lab reports grade; 2021 – 2023; normalized; xlabel (students), ylabel (grade).

The average and standard deviation of AM Lab and Total Lab are shown in Table 1 and Table 2, respectively. We observe that the 2018 – 2020 hardware lab displays a better performance than 2021 – 2023 software simulation lab offered due to COVID-19 isolation. The slight deterioration can be seen in AM lab and ECEN 325 total lab grade during COVID-19 isolation. One major difference between hardware lab and software simulation is that hardware lab was held in STC (Scott Technology Center) 120 laboratory class with oscilloscope, spectrum analyzer and function generator. However, software simulation lab was offered on-line. One teaching assistant (TA) was assigned for in-class lab classes. However, there was no TA for software simulation on-line classes. The duty of the TA in lab class was (1) to check attendance (present, absent, or late), (2) to check every milestones during the lab process. (3) to check successful completion of the lab. (4) to communicate with the ECEN 325 professor for any lab class issues. However, TA is not assigned to on-line software simulation lab and some students received only a low partial credit since they did not successfully finish the lab. The result is the reduced grade in AM lab and ECEN total lab grade seen in Table 1 for AM Lab Grade and Table 2 for Total Lab Grade. In the tables, we can also observe that the standard deviation is larger for 2021 – 2023 due to the partial completion of the lab of some students. However, we also see a larger standard deviation of 2020 in Total Lab Grade in Table 2. The phenomenon can be explained that a student did not submit a couple of lab reports and the total grade became lower as a result.

Table 1 AM Lab Grade Average and Standard Deviation

	AM Lab Grade	
Year	Average	Standard Deviation
2018	97.66	5.27
2019	96.25	4.35
2020	95.43	4.5
2021	89.89	6.68
2022	89.43	11.21
2023	90	6.74

Table 2 Total Lab Grade Average and Standard Deviation

	Total Lab Grade	
Year	Average	Standard Deviation
2018	93.56	10
2019	94.07	5.02
2020	88.71	12.16
2021	85.72	6.77
2022	86.34	10.03
2023	83.91	17.4

5. Future Works

In fact, for a fair comparison, a TA needs to be assigned to the software lab. During the COVID-19 isolation, all the labs in ECEN 325 class were done via on-line and no TA was assigned to help students to complete their labs. Students emailed the course instructor when they have issues in performing the lab and the instructor explained and resolved the issues via

email communications that could be time-consuming compared to the TA present in the lab hour. Another critical issue is to evaluate students' mastery of the subject in ECEN 494 (ELEC CAPSTONE 1), ECEN 496 (COMP CAPSTONE 1), ECEN 495 (ELEC CAPSTONE II), and ECEN 499 (COMP CAPSTONE II). These two issues are remained as our future works for an accurate evaluation and comparison of the two types of laboratory classes – hardware and software laboratories.

6. Conclusion

This paper presented the amplitude modulation lab conducted in hardware experiments and corresponding software simulation lab offered to satisfy the COVID-19 isolation requirements. We can see that the student performance evaluation of the software simulation lab was slightly lower than that of the hardware lab. We displayed the result of a lab class of ECEN 325 Communicaitons Systems that is a junior class in Electrical and Computer Engineering Department at the University of Nebraska. We illustrated a specific lab, AM, and the average grade of all lab classes of ECEN 325. In general, the student evaluation of hardware lab was shown to be slightly better than that of software simulation lab offered following the COVID-19 isolation requirements. We recommend that a teaching assistant be assigned to on-line software simulation lab class. The TA can play an extremely useful role in reducing the gap between the hardware in-class lab and the software simulation on-line lab. The assigned TA can check every milestones of the lab in the process, correct any mistakes, and make sure of the successful completion of the lab. Students' exposure to contemporary communication system software simulation tools such as System Vue of KEYSIGHT will certainly help prepare STEM (science, technology, engineering, and math) graduates for the jobs of today and tomorrow.

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