

Lemons into Lemonade!

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From 2007-2010 he was Professor and Chair of the Electrical and Computer Engineering Department at Boise State University, Boise, ID. From 2011-2012 he was the inaugural Signal Processing Education Network (SPEN) Fellow. From 2012-2014 he and his wife lived with 20 engineering students in the engineering residential college (ERC) on the Boise State campus.

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Abstract

This paper discusses a trial of offering two senior/first-year graduate classes in a 7-week format, one following the other. Thus, a student could complete two courses (6-credits), dealing with two closely related topics, in one semester. In this case, the courses were **Digital Communication Systems** and **Wireless Communications**.

During the first week of the first 7-week course, all of the in-class demonstrations and hands-on experiences needed to be shifted to online/remote delivery. This was primarily accomplished using the Amazon Web Services (AWS) AppStream, cloud computing system.

The planned real-world signal capture and analysis project changed to an optional attendance of a technical conference. All of our students choose to attend this conference at their own expense.

This paper will discuss these challenges and provide a selected assessment.

Introduction

The authors present one pre-COVID planned experiment and three COVID changes necessary to support senior and first-year graduate Electrical and Computer Engineering (ECE) courses.

1. The pre-COVID experiment was based on offering two senior and first-year graduate classes in a 7-week format, one following the other. Thus, a student could complete two courses (6-credits), in one semester, dealing with two closely related topics. In this case, the courses were **Digital Communication Systems** and **Wireless Communications**.
2. The first of the COVID changes dealt with a lesson-one pivot to all instruction being online. This was due to a unanimous preference by the enrolled undergraduate students.
3. The second change resulted from all instruction going online. Hands-on operation of a hardware vector signal analyzer (VSA hardware) and software-based vector signal analysis (VSA software) of real-world digital communication signals was no longer possible.
4. The third change resulted from University Administration promulgated guidance saying, "It's okay to take a review day, to reassign class time for students to work on a project, or to reduce student workload." This led to the alternate strategy of participation in a virtually-delivered technical conference by all enrolled students.

More details regarding these changes, and the course outcome, are given below.

7-week, Back-to-Back Course Offerings

The planning for this trial was completed in the Fall of 2019 (pre-COVID); however, during the Spring of 2020 when our university pivoted to all classes going online, most of these plans began to unravel. After interviewing all of our engineering students at the end of the Spring semester, it

became very clear that our upper division ECE students did not prefer online/remote engineering education. Accordingly, plans were made to hold these new 7-week trial classes in a face-to-face manner.

This was the first offering of the **Digital Communication Systems** course; the course overview and learning outcomes are provided below.

Course overview: “An introduction to digital communication systems focusing on the physical layer (PHY). A review of concepts including Shannon theory, Nyquist sampling theory, optimal detection under Gaussian white noise, and various modulation schemes. Building blocks of a digital receiver, including time and frequency synchronization, equalization and precoding, error-correction coding/decoding, and the available tools using vector signal analysis (VSA) techniques. Exposure to some advanced communication technologies such as Multiple-Input Multiple-Output (MIMO) and 5G systems.”

Learning Outcomes: After taking this course, you will be able to:

- Design a digital transmitter in MATLAB
- Design a simplified digital receiver in MATLAB
- Be able to analyze and identify various modulation schemes using VSA software
- Test/characterize your transmitter using VSA software
- Test your transceiver system in MATLAB

Additionally, two practicing engineers wanted to take the **Digital Communication Systems** course, but could not attend in-person due to fact that with the class starting at noon, it conflicted with their work hours. Additionally, due to the 7-week format, the traditional one hour and 15-minute class period extended to two hours and 30 minutes with a break in between the back-to-back scheduling periods. This required an online-only section to allow these practicing engineers to participate in the class.

The Lesson One Pivot to Online Only

An unintended consequence of creating the online-only section for the practicing engineers was that all of the enrolled graduate students shifted their enrollment into this section. This meant that the only students actually attending the face-to-face class were the undergraduate students. Remembering that just a few months ago, upper division ECE students expressed the opinion that they did not prefer online/remote engineering education, this was not viewed as a problem and the course proceeded as planned. However, during the first class meeting (lesson one), the undergraduate students unanimously requested that the course be delivered online.

The VSA Hardware and Software Student Experience

With all instruction now online, hands-on operation of the VSA hardware and VSA software as originally envisioned was no longer possible. Real-time in-class videos helped explain the hardware issues and 30-day trial versions of the Keysight VSA software began to solve the software concern. However, with access to the VSA software needing to span the entire semester, other solutions were needed.

The Boise State University College of Engineering (COEN) Information Technology Services (ITS) department had already put in place the AppStream remote hosting system made available by Amazon Web Services (AWS). This remote access to several engineering software tools was serendipitously put in place for the Spring 2020 semester. As shown in Figure 1, these were the programs available to COEN students during the Fall 2020 semester.

Construction Management	Civil Engineering	Electrical & Computing Engineering	Mechanical & Biomedical Engineering	Materials Science Engineering	Senior Design
Asta Power Project 15.002	ArcGIS 10.7.1	Matlab 2020a	Abaqus 2019	CES Edupack 2020	ArcGIS 10.7.1
Autodesk Navisworks Manage 2021	Autodesk AutoCAD 2021	Vivado 2019.2	Solidworks 2020	Comsol 5.5 CK	Matlab 2020a
Autodesk Revit 2021	Autodesk Civil 3D	Keysight VSA	MD Solids 4.1		Solidworks 2020
OnScreen Take-Off 3.97	Autodesk Revit 2021				Trace 700
	Matlab 2020a				CDS Designer
	Risa 3D v19				
	Stella Professional				

Figure 1. College of Engineering programs available remotely using AWS AppStream.

During the first week of the 7-week semester, all of the in-class demonstrations and hands-on experiences, with numerous pieces of radio frequency (RF) test and measurement equipment (T&ME), the commDSK app within the winDSK8 program [1-5], signal acquisition, using a vector signal analyzer, and analysis using state-of-the-art vector signal analysis software, were shifted to online/remote delivery. This was primarily accomplished using the Amazon Web Services (AWS) Appstream, cloud computing system. AppStream also handled the license server issues associated with the VSA software. Additionally, the Keysight VSA software only runs on a Window-based computer [6]. One student only had a Mac, so the AWS AppStream option also solved this problem.

Student homework emphasized MATLAB creation and analysis of a number of digital communication signals. Eventually, these signals were played through a computer sound card and captured by the VSA hardware operating in baseband mode. The VSA software recorded the signals and the recorded files were returned to the student for analysis. Thus, the students

accomplished almost all of the course's original VSA instructional objectives. A typical student result is shown in Figure 2.

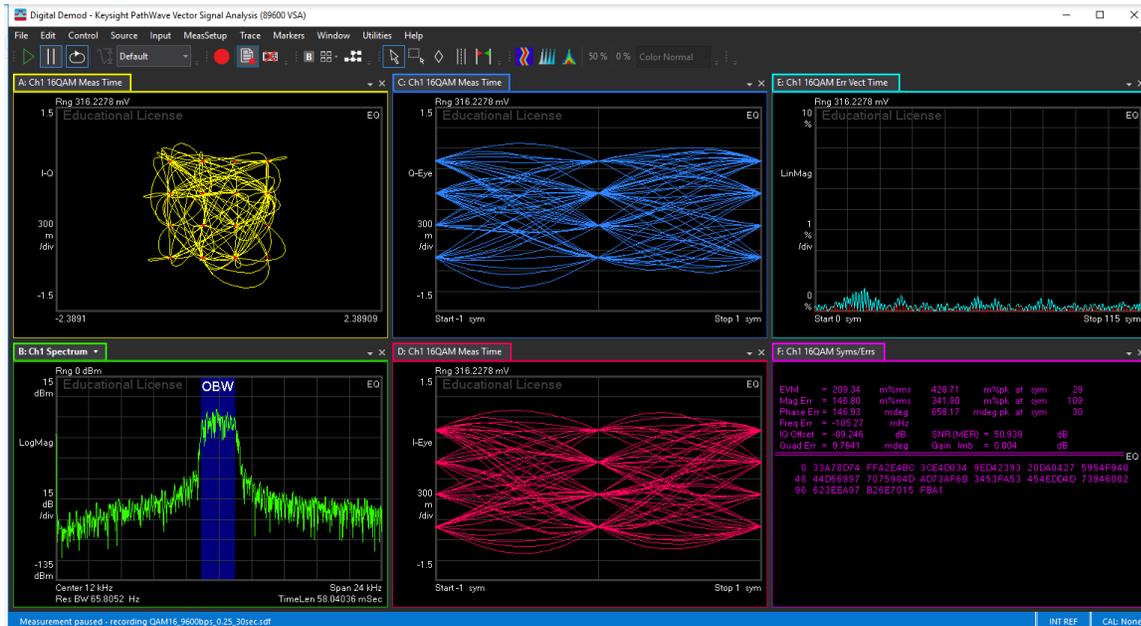


Figure 2. Student generated, 16-QAM signal being analyzed using the VSA hardware and software.

Reassigning Class Time

The planned hands-on, real-world signal capture and analysis project was shifted to the optional attendance of a technical conference. Serendipity had struck, and the IEEE DSP Online Conference was available for only \$20 per person for early registration [7]. No student discounts were offered. This was a single track, 2-day event, 12 hours per day, and was extremely well done. Presentations were very helpful and/or tutorial for most students. About 500 attendees registered, as compared to thousands for a premier IEEE Signal Processing Society (SPS) event such as the International Conference on Acoustics, Speech, and Signal Processing (ICASSP).

fred harris (yes, he does not believe in capitalization of his name), the author of a well-known multirate signal processing textbook [8, 9], was presenting two sessions at this conference. Reference [9] was published after these courses were completed. Attending this conference was optional, but if a student chose not to attend, they would need to complete a multi-rate signal processing assignment. All of the students choose to attend this conference at their own expense.

For another comparison, the IEEE Power and Energy Society (PES) General Meeting (GM) cost \$100 to attend virtually this past Summer. The last PES GM that the author attended in Portland, OR, cost a few thousand dollars. This may not be a fair comparison, since this is comparing a two-day, single-track event to 5-day, multi-track event.

Post-conference discussions were held during class. One double class period (2.5 hours of educational class time) became about 24-hours of available educational content. This was one of

the least expensive ways that the authors had ever accumulated so many professional development hours (PDHs) so quickly and inexpensively. PDHs are required in most states of the U.S. to maintain an active professional engineering (PE) license.

During the second 7-week, **Wireless Communications** course, all the students participated in the 3rd IEEE Workshop on 5G Technologies for First Responder and Tactical Networks, co-sponsored by Johns Hopkins University Applied Physics Lab and the U.S. Department of Homeland Security Science and Technology Directorate. This was a free, 1-day, 6-track event, with 13 patron breakout sessions. Students choose which track they attended.

Assessment

While the authors are firm believers in the utility of assessment, given the small class size (10, half undergraduate and half graduate students), the following results are, at best, anecdotal in nature.

In addition to the traditional end-of-course evaluations conducted by the university, the students were also asked three extra questions. The results are shown in Figure 3. The undergraduate results are shown since the department's primary concern was with the pace at which this information was being presented to them. The last two questions dealt directly with course objectives. The bar labeled "Dept. Mean" plots the same information as the "Course Mean" bar and therefore, provides no new information.

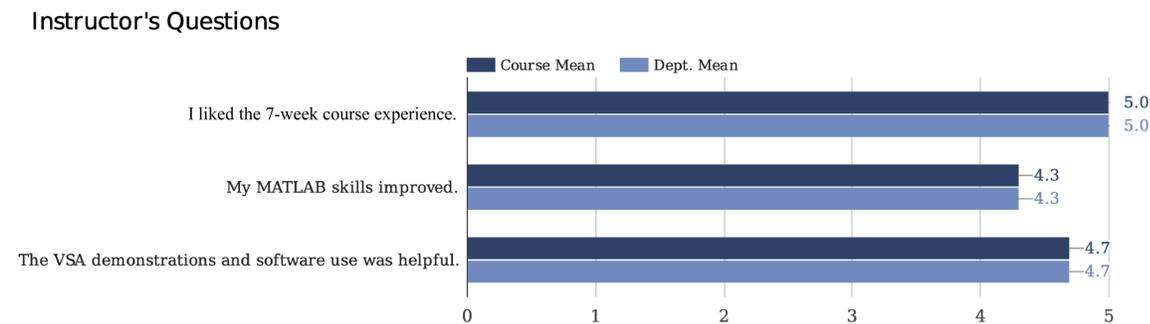


Figure 3. End-of-course evaluation instructor question results (undergraduate only).

As a homework assignment, students were asked the following questions and a shortened version of their responses are provided below.

Concerning conference attendance, 80% of the students had not previously attended a technical conference. Those that had attended a conference, had attended a Society for Women Engineers (SWE) event.

- Estimate how much of the conference you have already viewed (in percent)?
 - Average was 14%, maximum was 20%.

- Remembering that the conference recordings will be available for one-year, estimate how much of the conference, in total, *you plan to view* (in percent)?
 - Average was 56%, maximum was 100% (20% of students).
- What was the title of your favorite session?
 - 80% selected fred harris' presentations discussing multirate techniques.
- What was your impression of the multirate signal processing topics presented by fred harris?
 - All of the comments were extremely positive, but representative of the class comments was, "He was a great presenter, I really enjoyed his vast knowledge and his method of delivery was very easy to follow, and I liked his humor and nerdy jokes."
- Given that traveling to and attending multiday technical conferences usually costs thousands of dollars, how much of *your own money* would you be willing to spend to attend such an event?
 - Average was \$733.
- Do you believe the conference was worth the amount that you paid?
 - All students said Yes, some added ... "YES!" ... "A bargain" ... "A steal" ... "Perfect for students" and "Yes, and thanks for setting this up."
- In hindsight, what is the maximum amount that you would have been willing to pay again, to attend this same conference?
 - Average was \$117.
- Did you prefer to use the VSA software on your own computer or using the COEN provided, AppStream version? Why?
 - 80% preferred their own computers. This was primarily based on speed and AWS AppStream 2-minute load time.
- Did you experience any difficulty in using the COEN provided, AppStream version of the VSA software? If so, please explain your difficulties.
 - All students said No and added, other than speed. The 2-minute load time, internet speed/data rate/throughput seemed responsible for video quality/update rate and student satisfaction.

Conclusions

The 7-week course offering was a huge success, especially among the better prepared graduate students. The undergraduate students commented that, at times, the material was a challenge to assimilate given twice the pace of a traditional ECE course.

Students in general are now very familiar with Zoom and other remote learning tools. In Spring 2020, the majority of Boise State University ECE upper division students didn't want online classes and actually protested having them. Now they are requesting online course delivery.

All of the students had full access to the Keysight VSA software, both trial versions on their Windows-based computers and online via our College of Engineering provided, Amazon cloud computing resource called AppStream. Due primarily to the video update rates of their computers, the students preferred their local version of the same software. This will continue to be a problem as long as broadband data rates are less than optimal.

AWS AppStream data showed that the 10 students spent about 90 hours using the VSA software. This is over and above the time they spent on their trial versions on their own computer. This represents much more time than would have been allowed for hands-on use of the VSA hardware and software tools during the in-person version of the class.

Conference attendance, even when self-funded, was a huge success with students and is very much consistent with encouraging academic curiosity.

Finally, given the realities of COVID (the lemons) we have made the best of the situation and tried to create lemonade! Overall, the authors are encouraged by the results.

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