

Interactive Browser-Based Digital Communications Laboratory

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Abstract: Being able to interact with and visualize the concept of digital communications through different forms of hands-on experiments is a crucial learning process for electrical/electronic engineering students to gain a better understanding of the subject. This paper presents a user-friendly browser-based digital communications training platform that allows students to interactively perform experiments covering topics like basic types of signals, lowpass filtering, matched filtering, baseband/passband modulations, signal multiplexing, and channel coding. Signals along the communication chain, i.e., at various points from the transmitter to the receiver, can be displayed and visualized on any standard web browser. Having a browser-based nature, the developed training platform allows for both offline and online uses. Consequently, it can be set to operate as a standalone, intranet-based, or Internet-based application.

Keywords— digital communications, signal processing, laboratory, web browser, interactive

1. Introduction

In Thailand and some neighboring countries, a lot of educational institutes lack laboratory equipment for teaching and learning digital communications, considered as an important technical subject in the age of digital information. While efforts exist to develop low-cost hardware-based laboratory kits to alleviate the equipment shortage [1], an immediate improvement can be provided through a web-based or browser-based approach.

Although digital communications involves almost all activities in modern lifestyles, e.g., talking over a phone call, chatting in a social network, etc., the underlying technologies are usually unseen by users. This is because almost all transmitted data signals cannot be seen, heard, or touched. Without educational tools designed to make these signals visible, how data signals are actually transmitted over a physical medium remains a mystery to a large number of students.

While drawings of various types of data signals are available in textbooks, e.g., [2], they are often limited to few examples, which are passively absorbed by students. To stimulate more interest in the subject, an interactive training platform that allows students to actively determine data bits and various system parameters would be beneficial.

Several courses on digital communications rely on using computational software, e.g., MATLAB or Octave [3], [4], as a simulation tool to create data signals and perform various signal processing steps in the communication chain [5]. Such an approach is effective when students have some background in MATLAB/Octave programming. Otherwise, students may spend most of the laboratory hours debugging

MATLAB/Octave programs instead of thinking about how communication systems work.

The above-mentioned situations motivate us to develop a user-friendly browser-based digital communications training platform that will allow students to visualize important concepts in digital communications without a strong programming background. In particular, students may change system parameters simply by inputting their values through the platform's graphical user interface (GUI). Attempts are made to develop a system that can run on any standard web browser on any operating system, including Windows, Mac OS, and Android.

Section 2 describes underlying technologies and key features of the developed browser-based laboratory. Section 3 shows the list of topics covered up to now as well as example data signals that can be generated and displayed by the training platform. Section 4 presents some evaluation results obtained from various workshops organized in Thailand, with both Thais and non-Thais in the audience. Section 5 provides a conclusion and discusses plans for future extension.

2. Underlying Technologies and Key Features

In this section, the underlying technologies together with the key features of the developed browser-based digital communications training platform are described. The system has been designed with the following key features in mind.

1. The system shall cover fundamental topics in digital communications.
2. The system shall display signals at various stages in the communication chain, i.e., outputs from various components along the path from the transmitter to the receiver.
3. The system shall be interactive by allowing users to change input parameters and observe the corresponding consequences.
4. The system shall work for both offline and online scenarios.
5. The system's underlying application programs must be based on free software.

To achieve these goals, the training platform is developed using the JavaScript language [6], and can be run on any common web browser, e.g., Internet Explorer, Google Chrome, etc. All fundamental blocks in the digital communication systems are realized in the JavaScript environment, including transmitter/receiver, channel encoder/decoder, digital modulator/demodulator, pulse shaping filter/matched filter, and transmission channel.

In addition, a graph-plotting library called "flotcharts" is also incorporated; it offers a simple usage of its application

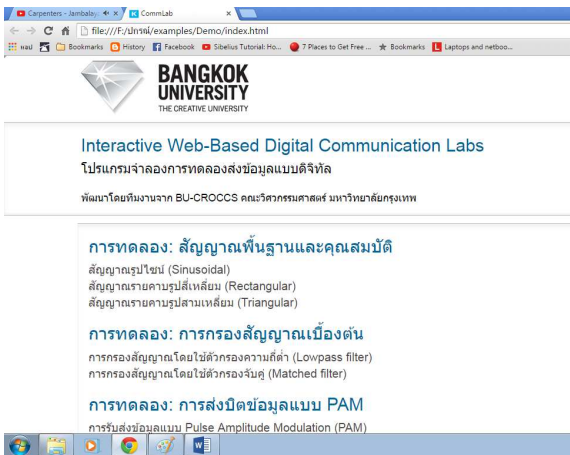


Figure 1. Starting window of the developed training platform.

program interfaces (APIs) for displaying different types of graphs. The JavaScript-based implementation of digital communications in conjunction with the graph-plotting library form the interactive browser-based digital communications training platform that can be operated either offline or online and is license free.

3. List of Topics and Example Data Signals

So far, the developed browser-based training platform provides interactive hands-on laboratory sessions covering the following topics, as shown on the starting windows of the platform in Fig. 1

1. Basic signals and their properties
2. Lowpass filtering and matched filtering
3. Pulse amplitude modulation (PAM)
4. Pulse width modulation (PWM)
5. Pulse position modulation (PPM)
6. Amplitude shift keying (ASK)
7. Frequency shift keying (FSK)
8. Phase shift keying (PSK)
9. Quadrature amplitude modulation (QAM)
10. Time/frequency/code division multiplexing
11. Error detection using parity check codes
12. Error correction using Hamming codes

Common to all the topics is the interactive feature of the developed training platform. In particular, students can specify transmitted data bits as well as some system parameters (when applicable) and see the effects of any change on the data signals.

Fig. 2 and 3 show example data signals for binary PAM and binary ASK, respectively. In each figure, the transmitted data signal is shown in yellow while the matched filter output at the receiver is shown in blue. It can be seen from Fig. 2 that, in binary PAM, bit 1 is mapped to a rectangular pulse with a positive value, while bit 0 is mapped to a negative value. For binary ASK in Fig. 3, bit 1 is mapped to a carrier signal (sinusoidal) with a high amplitude, while bit 0 is mapped to a low amplitude.

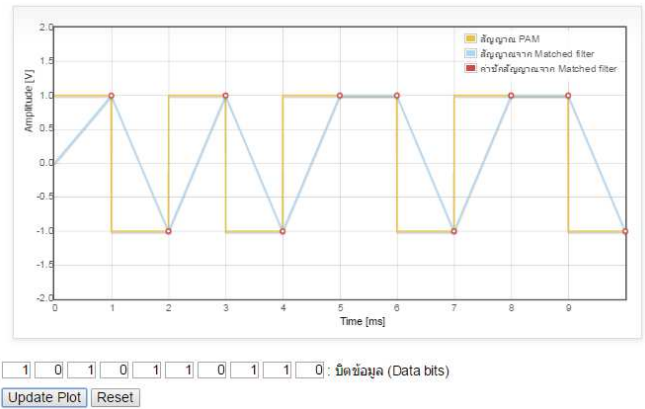


Figure 2. Transmitted PAM signal (in yellow) and matched filter output at the receiver (in blue); students can enter 10 data bits and see the effects on the signal waveforms.

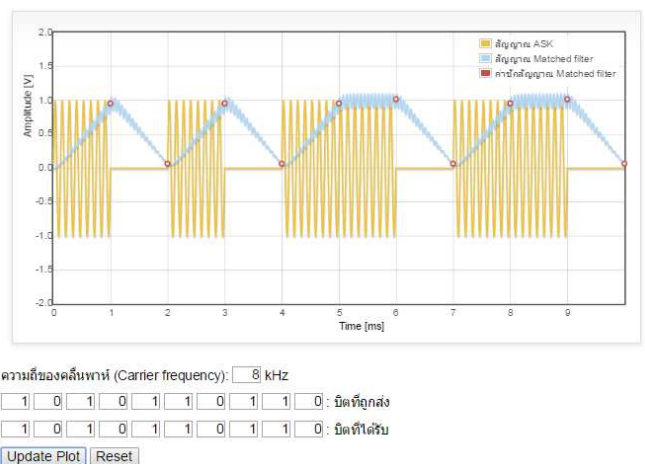


Figure 3. Transmitted ASK signal (in yellow) and downconverted matched filter output at the receiver (in blue).

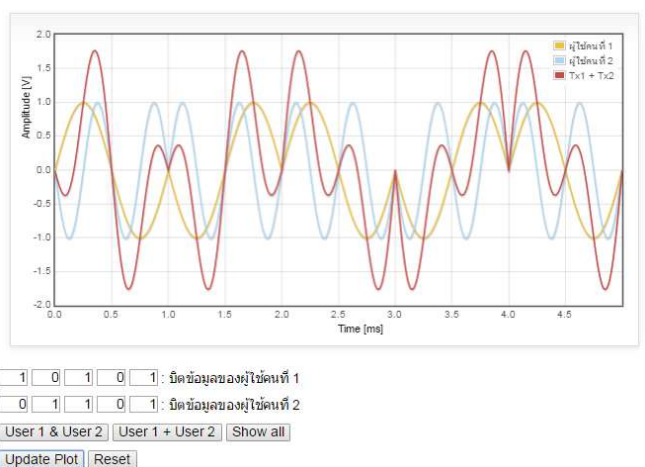


Figure 4. FDM signal (in red) with data from two users (in yellow and in blue); students can enter two sets of data bits, one set for user 1 and the other for user 2.

In each case, the 10 input boxes below the plot can be used to specify the 10 data bits, which are 1010110110 in Fig. 2 and 3. For ASK, a user can also specify the carrier frequency. By clicking “Update Plot” after changing data bits, a user can immediately observe changes in the data signals, making the laboratory experiences interactive.

Fig. 4 shows an example FDM signal (in red) resulting from multiplexing two data signals from two users at low and high carrier frequencies (shown in yellow and blue, respectively). Data bits are 10101 for user 1, and 01101 for user 2. Unlike before, FDM makes it difficult to indicate data bits from the signal waveform.

As an example of the interactive feature of the developed training platform, Fig. 5 illustrates a change in the data signal when transmitted data bits are changed from 1010110110 (as in Fig. 3) to 0101001101. As another example, Fig. 6 illustrates a change in the data signal when the carrier frequency is changed from 8 kHz (as in Fig. 5) to 16 kHz. Such interactive activities allow students to become more actively involved in the subject.

Finally, while Fig. 2–6 show screenshots from a personal computer, the training platform can be run on mobile devices as well. Fig. 7 shows the same experiment as in Fig. 3, i.e., ASK transmissions, but on a tablet as well as on a smartphone.

4. User Evaluation from Hands-On Workshops

We organized hands-on workshops on two occasions in Thailand. The first workshop was held at the ECTI-CON 2015 conference on 24 June 2015, with 25 participants. The second workshop was held at Asian Institute of Technology (AIT) on 3 July 2015, with 13 participants most of which are international students. Fig. 8 and 9 show the atmospheres at the two workshops, respectively.

In each workshop, due to a time limitation, a few experiments were chosen from the list of topics mentioned in Section 3. Participants ran the training platform on laptop PCs that were provided for them. The topics include baseband and passband modulation techniques.

At the end of each workshop, each participant was asked to evaluate the platform through a questionnaire. The evaluation results are shown in Table 1, with a strong agreement that the platform is easy to use without any requirement on programming skills. In addition, most participants agree that the platform can help them understand the fundamental concepts underlying digital communications.

5. Conclusion

We developed a browser-based digital communications training platform to help students visualize data signals used in digital communication systems. Since the developed platform is user-friendly and can run on any standard web browser on any operating system, we hope that it can be used to immediately alleviate the equipment shortage problem, e.g., in Thailand. In addition, students can learn on their own at any place at any time from their mobile devices, e.g., using a tablet or a smartphone. The platform can be run as an offline application or as an online web-based application.

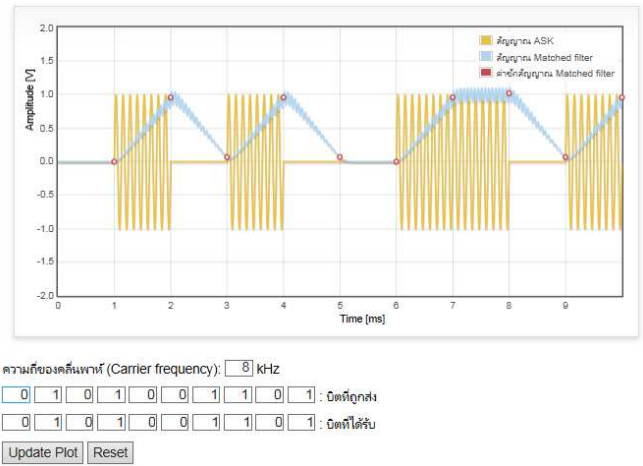


Figure 5. Modified ASK signals for data bits 0101001101 instead of 1010110110 as in Fig. 3.

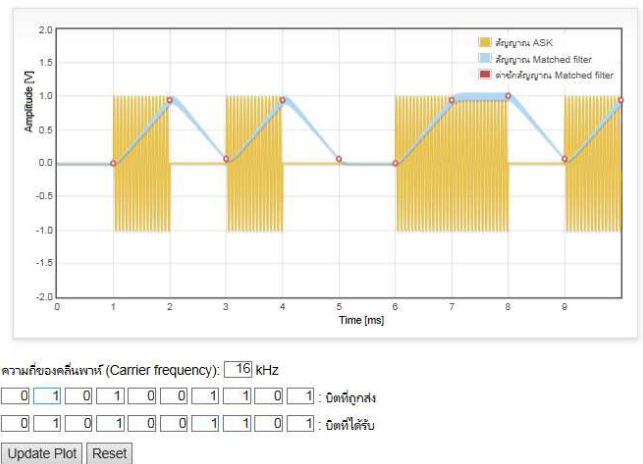


Figure 6. Modified ASK signals for carrier signal frequency 16 kHz instead of 8 kHz as in Fig. 5.

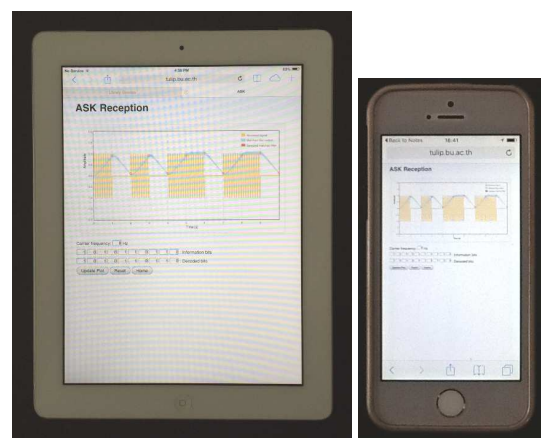


Figure 7. ASK experiment run on mobile devices, including a tablet (left) and a smartphone (right).



Figure 8. Atmosphere of the workshop held at the ECTI-CON 2015 conference on 24 June 2015.



Figure 9. Atmosphere of the workshop held at AIT on 13 July 2015.

Table 1. Evaluation results of the developed browser-based digital communications laboratory from the participants in two hands-on workshops; each answer ranges from the score of 4 (strongly agree) to 1 (do not agree).

Question	4	3	2	1	No answer
Easy to use for self learning	23	13	1	–	1
Easy to use for teaching	23	13	1	–	1
Helpful in understanding digital communications	16	17	3	–	2

Directions for future developments include demonstrations of how random noise, e.g., additive white Gaussian noise (AWGN), and other channel impairments, e.g., dispersion, can affect the transmission performance. Interesting advanced topics that will also be considered include multi-carrier modulation techniques such as orthogonal frequency division multiplexing (OFDM).

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