AC 2009-2021: THE APPLICATION OF MATLAB TO TEACHING COMMUNICATION SYSTEMS

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Application of Matlab on the Teaching of Communication Systems

Abstract
Matlab has become a widely used tool for teaching and learning in various Engineering programs. In author's electronics technology program, many students do not have a strong calculus background, which is the basic requirement for the communication systems course. Therefore, it is helpful to have a tool like Matlab to help them understand the concepts of signal, Fourier theorem, random noise and modulation / demodulation. In this paper, we present the experiences of teaching communication systems with the help of Matlab.

Introduction

"Communication systems" is offered as a senior level course for Electrical Engineering majors in most universities. Its primary objective is to introduce the basic techniques used in modern communication systems and to provide fundamental tools and methodologies used in the analysis and design of these systems. It requires the students have the background in calculus, linear algebra, basic electronics circuits, linear system theory, and probability and random variables. The author works in the Department of Engineering Technologies and the course of communication systems is open for junior year students. However, the problem is that our students do not have the necessary mathematical background, which means it is not easy for them to understand Fourier Transform, modulation theory, nor filter design theory. Throughout my teaching, I have found Matlab to be an useful tool in helping students understand the concept and theory of the communication systems.

Introduce some concepts of communication system with Matlab

The most important concept in communication system includes the time and frequency domain analysis, modulation/demodulation techniques, noise in the modulation system, and filters design. During my teaching, I have found Matlab to be a useful tool for students to understand these basic topics. One possible question faced by students is "Why is the frequency domain needed?" In response, Matlab plots of cosinusoidal signals in time domain and frequency domain are shown to them respectively. Afterwards, they find the plot in frequency domain to be very simple. In addition, they also learn to write their own Matlab code to plot different signals.

Before an information-bearing signal is transmitted through a communication channel, some type of modulation process is typically utilized to produce a signal that can easily be accommodated by the channel. We discuss various types of modulation techniques in our communication system class. The modulation process translates an information-bearing signal, usually referred to as the message signal $m(t)$, to a new spectral location depending on the intended frequency for transmission. The two basic types of analog modulation are continuous-wave modulation and pulse modulation. In continues-wave

modulation, a parameter of high-frequency carrier is varied proportionally to the message signal such that a one to one correspondence exists between the parameter and the message signal. For a sinusoidal carrier, a general modulation can be represented as

$x_c(t) = A(t)\cos(\omega_c t + \phi(t))$

where ω_c is the carrier frequency. Depending on the format of the amplitude parameter $A(t)$ and the phase parameter $\phi(t)$, modulation technique can be classified as amplitude modulation AM and frequency modulation FM. The modulated carrier for amplitude modulation is of the form $x_c(t) = (A + m(t))A_c \cos(\omega_c t)$, where ω_c is the carrier frequency and A_c is the carrier amplitude. In my first class of amplitude modulation, the Matlab tool box is used to show students the plots of a real message signal $m(t)$ and the modulated carrier x_c. An example is presented in Figure 1. From this figure, it is obvious to find that the period of the original signal is much bigger than the modulated signal. In another words, the frequency of the modulated signal is much bigger than the original message. The students immediately understood the idea that modulation changes the message's frequency and the envelope of the carrier signal looks like the original message. The plot highlights their findings.

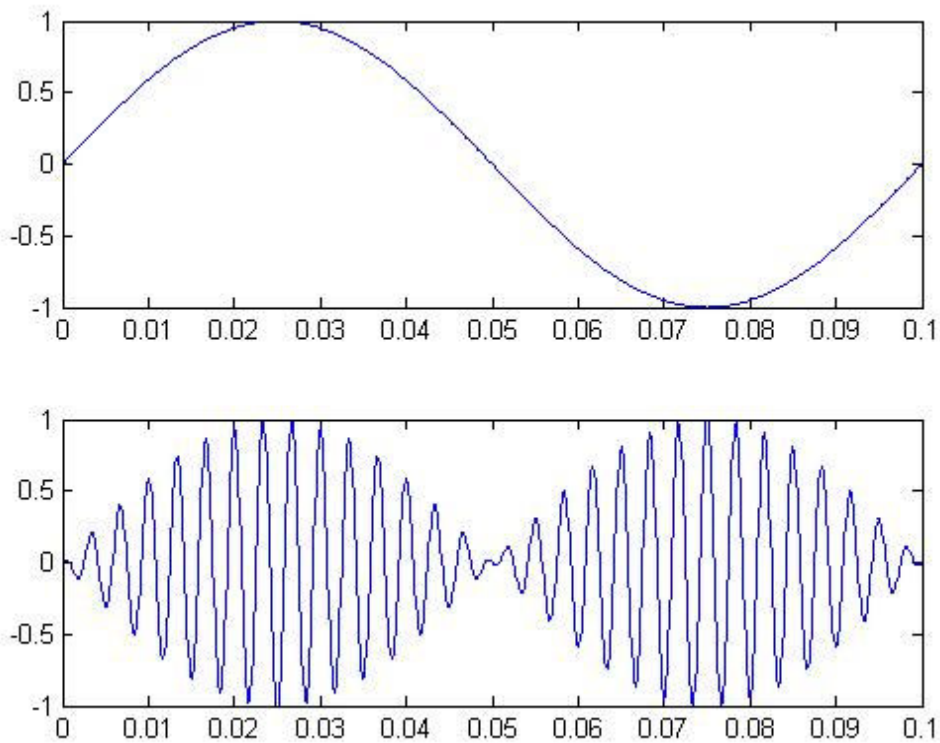Sinusoidal wave and its modulated carrier

Figure 1

In order to introduce the concept of demodulation, another example is presented. This example illustrates the basic format of the analog modulation and demodulation functions

by sampling an analog signal and modulating it. Then, it simulates an additive white Gaussian noise (AWGN) channel, demodulates the received signal, and plots the original and demodulated signals. Figure 2 shows the plot. From this plot, students found that the recovered signal is similar to the original one, except for the noise influence.

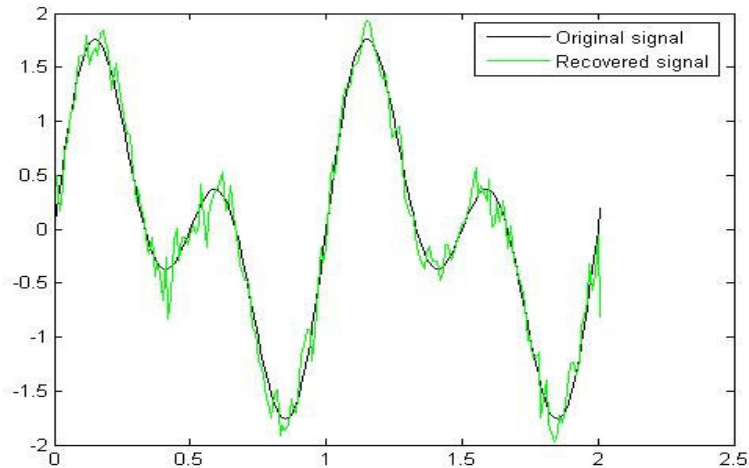Original signal and demodulated signal

Figure 2

Filter design plays an important role in communication systems. Digital filter design has many advantages. There are several structures, such as FIR transversal structure, IIR-Direct forms, Ladder WD network, Lattice WD network etc. After introducing the concept and methods of filter design, a project is assigned to students: to recode his/her voice wave and then add some noises. Observe the difference between them. They had the concept of "good" signal and "noise" signal. Figure 3 shows an example of original signal and noise signal generated by Matlab.

The students design digital filters to filter the noise from the original message. The specification for the design of filter is $\omega_p = 20\,\text{rad/sec}$, ripple is 0.1dB. The transfer function is given by

$$H(z) = \frac{0.0013 + 0.0088z^{-1} + 0.0264z^{-2} + 0.0441z^{-3} + 0.0441z^{-4} + 0.0264z^{-5} + 0.0088z^{-6} + 0.0013z^{-7}}{1 - 3.0328z^{-1} + 5.2558z^{-2} - 5.9659z^{-3} + 4.6506z^{-4} - 2.4636z^{-5} + 0.8214z^{-6} - 0.1343z^{-7}}$$

A noised signal $x(t) = \sin(3t) + \dfrac{1}{2}\sin(30t)$ is passed through the filter and a filtered signal is obtained which is almost the same as the original message. Figure 4 is the result after using IIR filter. Comparing with original message in Figure 3, there is a little bit delay in the filtered one in Figure 4. Figure 5 is obtained by using the designed wave digital filter. Through this project, students learned a lot about filter design and at the same time their Matlab programming skill is also improved.
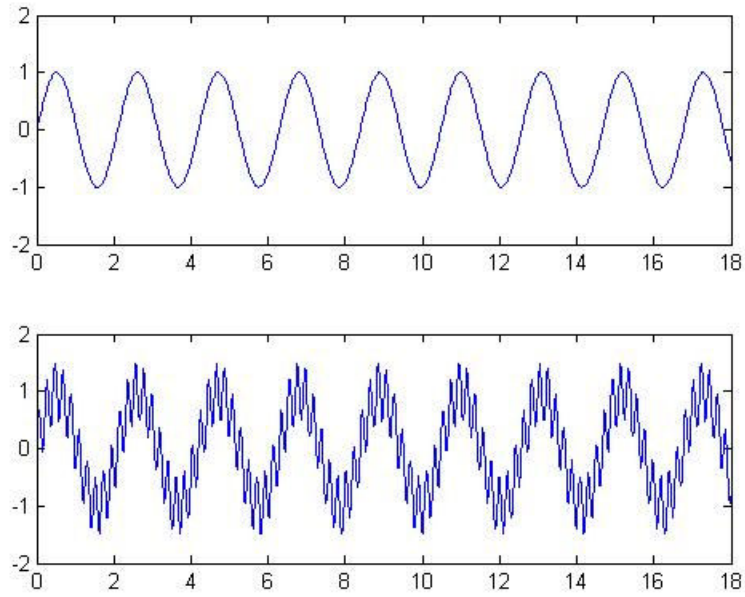
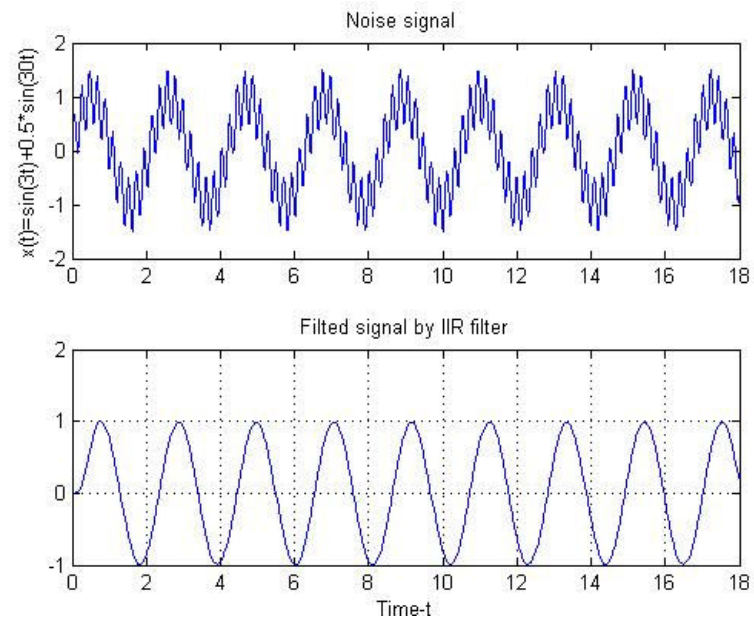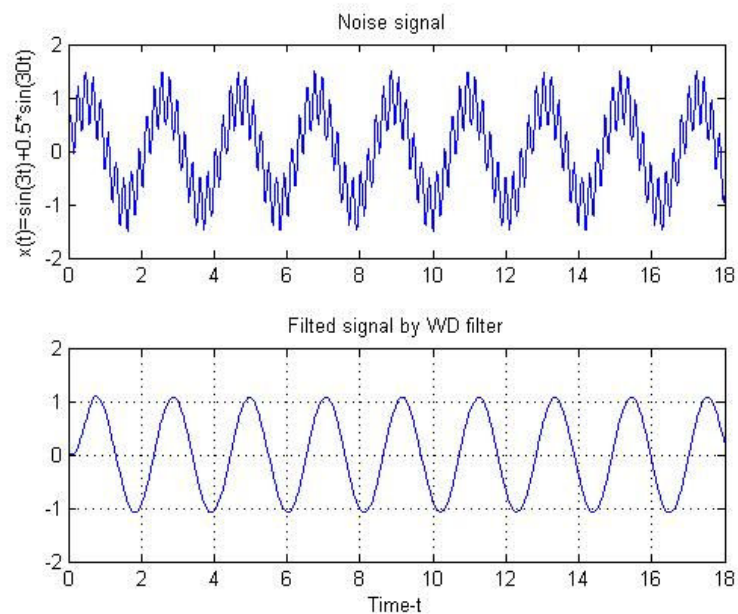Original signal and noised signal

Figure 3

Figure 4

Figure 5

Conclusions

An experience of teaching "communication systems" course in a Department of Engineering Technologies is presented in this paper. We applied the use of Matlab to the class room teaching and find that Matlab is a power tool to motivate students' interests to learn this course and understand the concept, theory and techniques in communication systems.

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Bibliography

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