

# Upgrading E-learning of basic measurement algorithms based on DSP and MATLAB Web Server

Milos Sedlacek<sup>1</sup>, Ondrej Tomiska<sup>2</sup>

<sup>1</sup> Czech Technical University in Prague, Faculty of Electrical Engineering, Technicka 2, CZ-16627  
Prague 6, Czech Republic,

phone: +420 2 2435 2177, fax +420 2 3333 9929, E-mail: sedlaceM@fel.cvut.cz

<sup>2</sup> Czech Technical University in Prague, Faculty of Electrical Engineering, Technicka 2, CZ-16627  
Prague 6, Czech Republic,

phone: +420 2 2435 2187, fax +420 2 3333 9929, E-mail: tomiso1@fel.cvut.cz

**Abstract**-The paper presents an upgraded version of an application of MATLAB web server, one of MATLAB toolboxes, for teaching/learning some selected measurement algorithms important in processing discrete-time signals in measurement. The original version is described in [1] and [2]. The topics included are DFT/FFT (demonstration of DFT basic properties and DFT application in spectrum analysis and detection of weak tones close to a strong tone), FIR filters (including the important moving average filter), basic IIR filters and some basics of stochastic signal processing in time domain and amplitude domain including finding SNR using correlation analysis. This upgraded version of MATLAB web server application is currently replacing an old one in teaching signal processing at Department of Measurement of the CTU in Prague, Faculty of Electrical Engineering, for both the students studying in Czech and (mostly Erasmus students) in English.

## I. Introduction

The role of Internet in teaching and learning, an important part of E-learning, is steadily increasing. A very powerful instrument suitable for teaching wide range of topics connected to digital signal processing is MATLAB Web Server, one of the MATLAB toolboxes. This toolbox allows preparing environment for teaching/learning all topics covered by MATLAB and its toolboxes for persons having access to web without necessity of installing MATLAB on their computers, and even without the necessity to know MATLAB. This paper deals with using MATLAB web server to the distant teaching of some basic signal processing algorithms often used in measurement. This application of MATLAB web server was originally prepared at the Department of Measurement of the Faculty of Electrical Engineering of the Czech technical University in Prague and it is in its original form described in [1] and [2]. The present paper stems from the upgrading of the original application inspired partly by the reviewers of paper [1] and partly by additional modification of both the MATLAB scripts used and text materials put on web pages corresponding the three laboratory exercises included, namely DFT/FFT, FIR Filters/IIR Filters and Correlation/SNR increasing.

The MATLAB Web Server enables its user to put data for computation on the web site on a client workstation (where a Web browser has to be installed), to send the data to MATLAB on the computer where run the MATLAB, MATLAB Web Server and the Web Server daemon. The calculations are performed according to the prepared MATLAB scripts and the computation results are sent back to the client computer. All computers in a computer laboratory can be used simultaneously for teaching the selected algorithm, but any web user all over the world can use this MATLAB web server application as well.

## II. Overview of changes in the original MATLAB web server teaching application [1]

The MATLAB web server application described in this paper can be found at the web site <http://merux.feld.cvut.cz/>, both in its version in Czech and in English. In the paper in press [1], the on-line version of proofs of which is available on Elsevier web pages, there is a description of the original version of MATLAB web server application for teaching DFT/FFT, FIR and IIR filters and Correlation analysis including SNR finding and increasing.

Each task consists from the software point of view of two parts. The first part provides graphical interface used to pass data from the user to MATLAB, the second part includes the MATLAB file used

for processing the data and sending the results back to the user. The graphical interface for data input and plotting the results is programmed in HTML language and in JavaScript language. HTML pages are designed using frames so that it is possible to display the input data form and later the resulting graphs in the same internet browser window. Framing is described in many HTML textbooks, e.g. in [4]). Framing allows splitting an HTML page into more parts. Each of those parts (i.e. frames) can be used to display a separate HTML page.

This application (in both its modifications in Czech and English language) has been successfully used in teaching basics of signal processing in measurement in the Department of Measurement of the Faculty of Electrical Engineering of the CTU in Prague since 2003. During this teaching period some suggestions of the involved teachers occurred and during reviewing process of [1], some useful hints of reviewers (not concerning the paper [1] text, but devoted to the web server application connected to the paper and used for teaching) were sent to authors. As a result of these suggestions, short theoretical introductions (available by a menu pushbutton “Introduction”) and several questions to each task to be used for preparation of student to the final exam (included at the end of each task’s “Instruction”) were added to all four partial tasks. Then there are some additional changes in the instructions of individual tasks and not connected to paper [1] reviewing process. These changes were included into the tasks in the winter semester 2006/2007 and are described below.

#### **A. A brief description of the “DFT/FFT” exercise and overview of changes in the original version of it**

The task in its original version allows the user to generate sinusoidal, rectangular or triangular signal with selected frequency and amplitude. One of the classical windows can be selected for signal windowing. Sampling frequency and displaying module spectrum in linear or logarithmic scale can be chosen. Zoom in both axes in time domain and frequency domain is also available. The task serves to show the students the importance of coherent sampling for preventing leakage in signal spectrum, effect of windowing on the spectrum of coherently and non-coherently sampled signals, and the possibility of increasing resolution in frequency domain by sampling several signal periods. The changes introduced to this task in this year are the following.

The input signal which generating a sum of two sinusoids was added. It allows selection of the two sinusoidal signals amplitudes and frequencies. This signal is used for inspection of window influence on detection of a weak harmonic signal close to a much stronger one that is non-coherently sampled. Also some more advanced windows (Blackman-Harris 4-term, Blackman-Harris 7-term and Kaiser with selectable value of  $\beta$ ) were added to the original version window selection for possible demonstration of trade-offs between main-lobe width and side-lobe level and/or fall-off. An example of using “dual sine” signal is in Fig.1 and Fig.2.

#### **B. A brief description of the “FIR filters” and in “IIR filters” exercises and overview of changes in the original version of it**

This task in its original version consists of two parts – one devoted to the FIR digital filters and the other one to the IIR digital filters. The tasks are intended for informing students about the shapes of frequency response of basic filter types, about the influence of filter order on transition width and about the effect of windowing the FIR filter impulse response on the overshoots and transition band width of the corresponding frequency response. The effect of all basic frequency selective filters on the input harmonic signal with non-zero DC component is also demonstrated. A uniformly or normally distributed noise can be added to the selected periodic signals.

The discrete-time unit impulse was added as an input signal, allowing inspection of the filters impulse response. Display of the frequency responses in dB was also added, allowing evaluation of pass-band and/or stop-band ripple values used by available filters design in corresponding MATLAB functions. Also the zoom in time domain was added, mostly because of with it connected possibility to use it for the detailed impulse response observing. A moving average filter with selectable length was added to the FIR filters task. The usefulness of this filter and proper selection of its length for filtering out an periodic disturbing signal when a DC signal is to be measured is demonstrated during this exercise (see the time domain and the frequency domain figures of this case in Fig.3 and Fig.4).

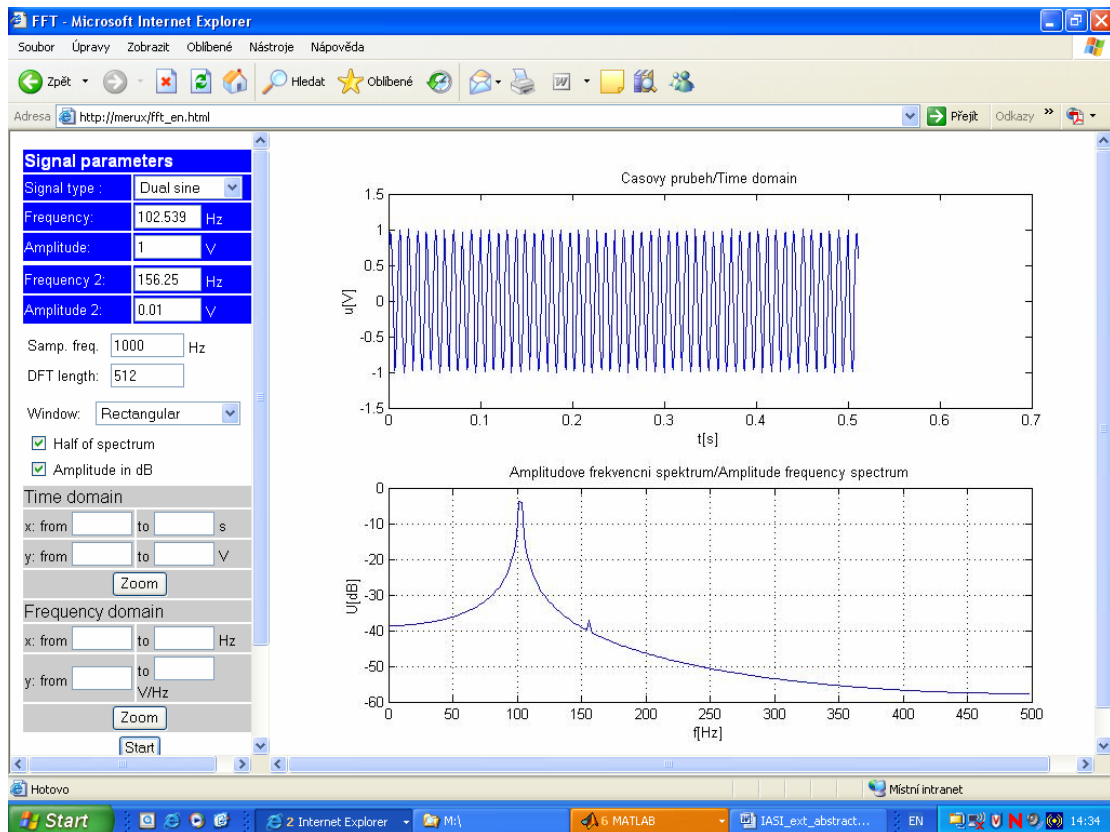


Figure 1. A PC screen in the task DFT, in lower right figure part is a spectrum of a coherently sampled weak signal close to a non-coherently sampled strong signal for rectangular window used

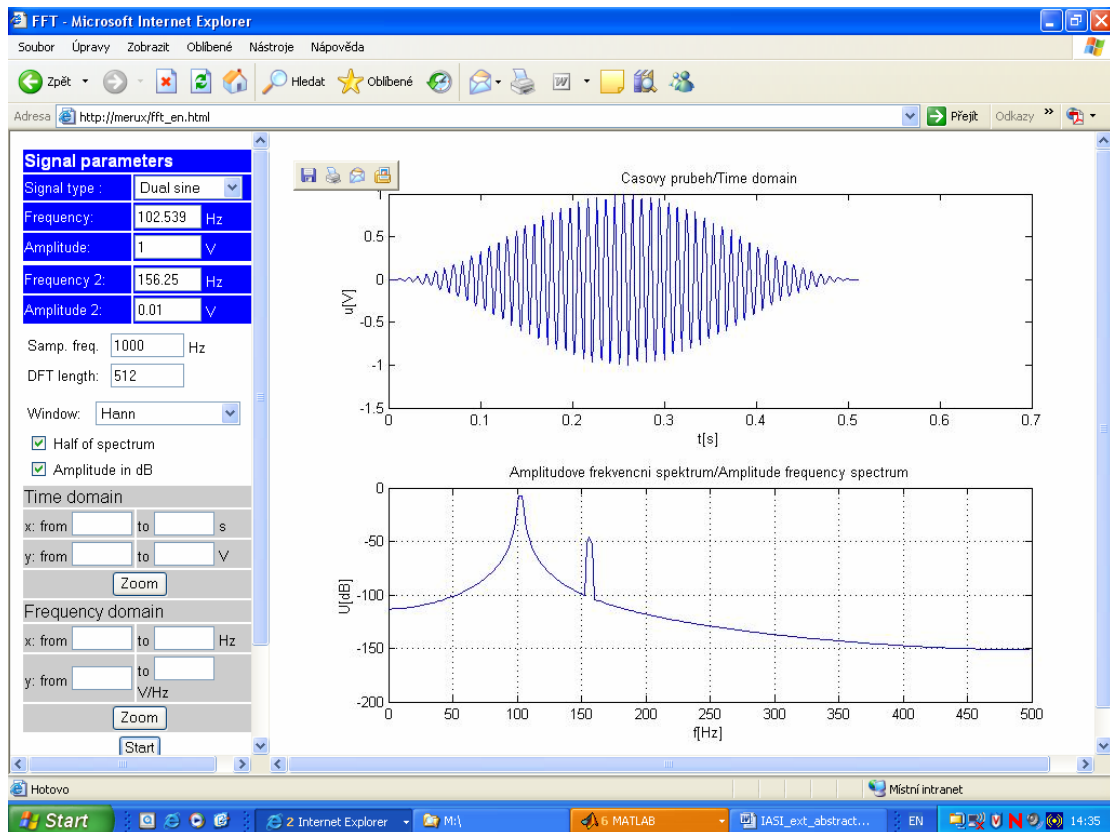


Fig. 2. A PC screen in the task DFT; in lower right figure part are spectra of a coherently sampled weak signal close to a non-coherently sampled strong signal for Hann window used. Compare to Fig. 1

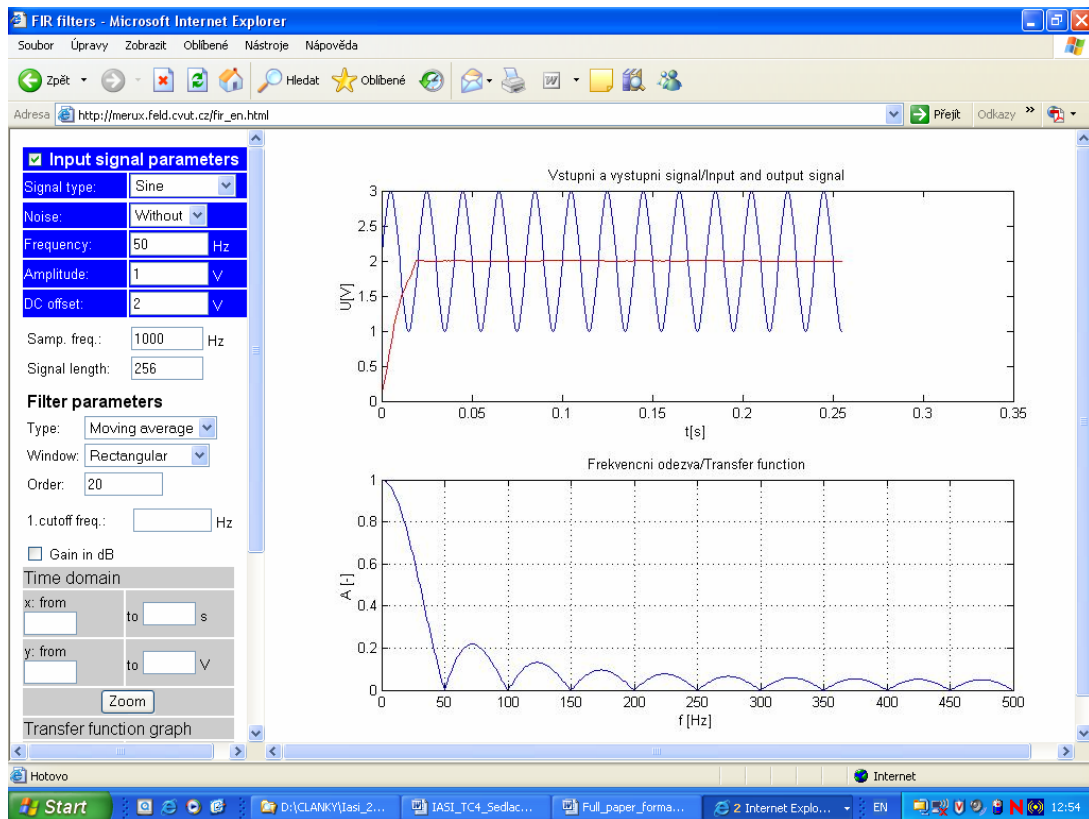


Figure 3. PC screen in task FIR filters, filtering-off the disturbing sinusoidal signal using moving average filter of suitable length, and the corresponding MA filter frequency response

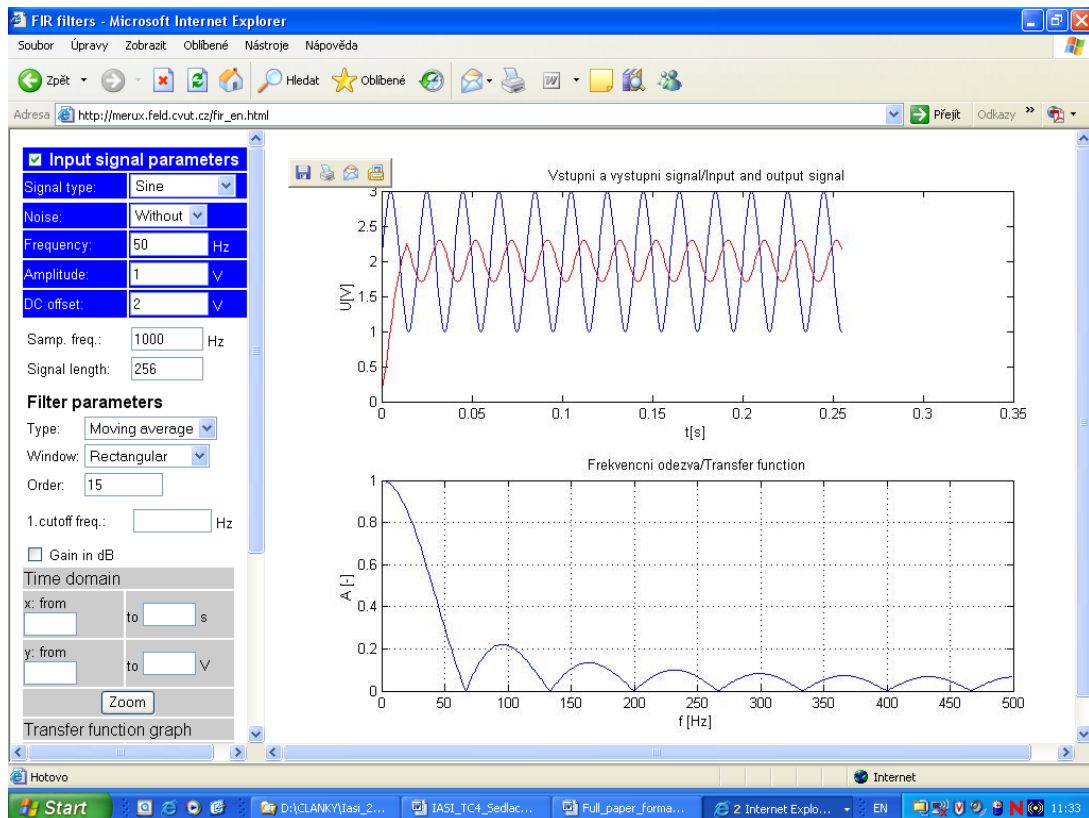


Figure 4. PC screen in task FIR filters, filtering-off the disturbing sinusoidal signal using moving average filter of the wrongly selected length, and the corresponding MA filter frequency response

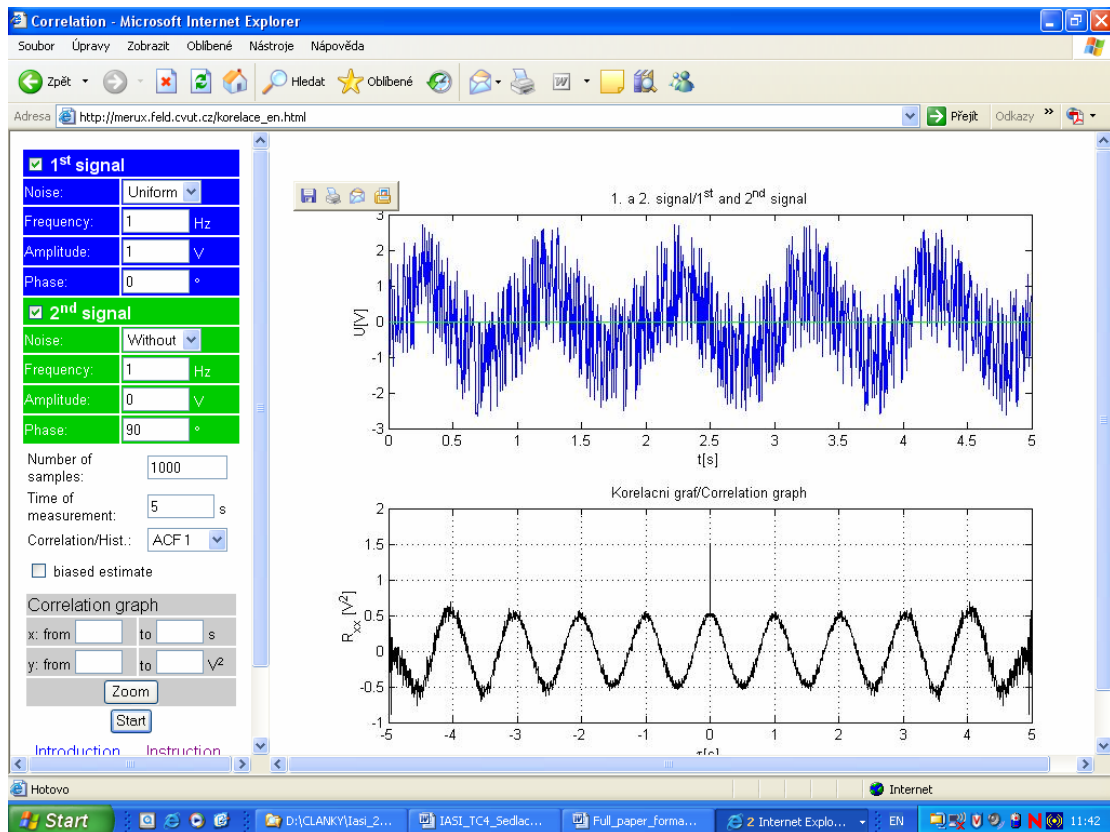


Figure 5. Auto-correlation function of a sinusoid with uniform additive noise – an unbiased estimate

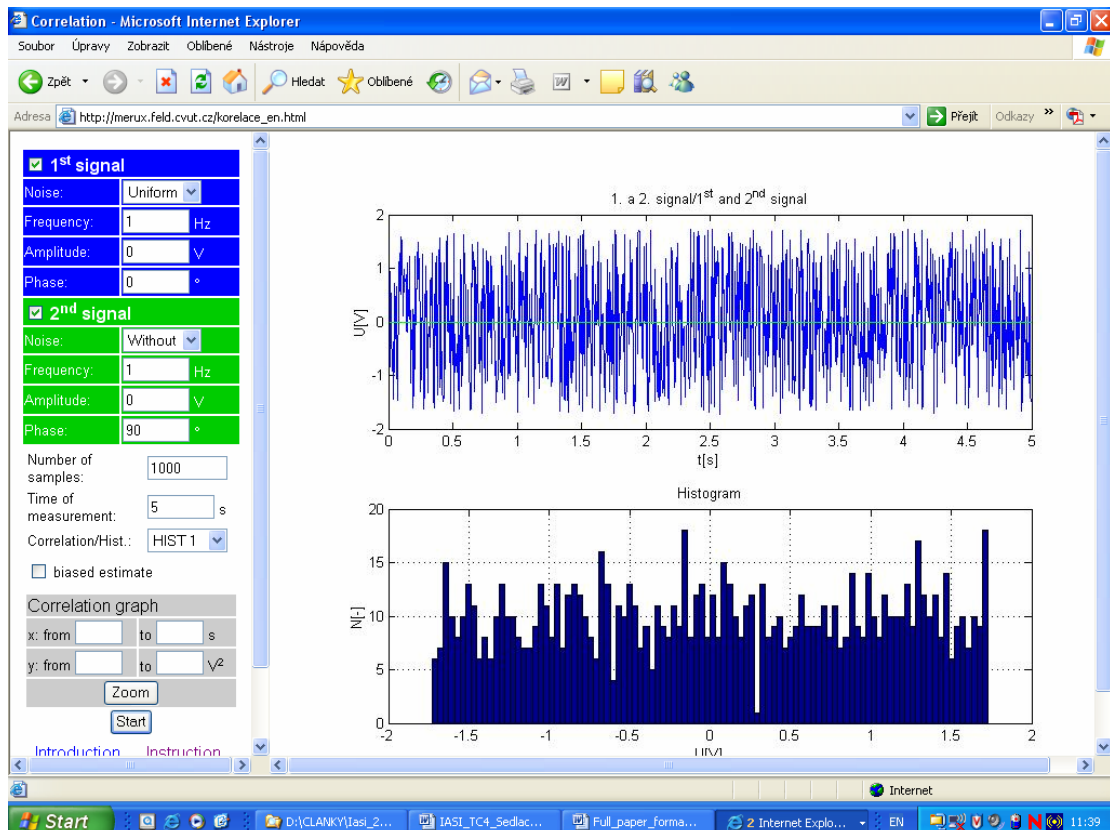


Figure 6. A histogram of MATLAB-generated uniformly distributed noise for not large enough number of samples (1000 signal samples are used in this example)



### C. A brief description of the “Correlation methods and SNR improvement” exercise and overview of changes in the original version of it

The aim of this exercise is to learn to use autocorrelation function of a noisy signal for finding power and RMS values of the signal and of the additive noise and the SNR of a noisy signal. The exercise will also demonstrate the autocorrelation functions and histograms of MATLAB-generated white noise with uniform or normal amplitude distribution, and a possibility to increase SNR using digital filtration of noisy signal.

Two sinusoidal signals with identical frequencies and different phases are generated and a uniformly distributed noise is added to the first signal, while a normally distributed noise is added to the second signal. Both the noises have the same standard deviation. Auto-correlation and cross-correlation functions (more precisely: correlation sequences) of the two noisy signals are displayed, and both biased and unbiased correlation function estimates are used. SNR of both signals are found using ACF values in origin and in one of its periodic local maxima after sufficient decrease of the ACF of noise. (Since the generated noise is approximately white, its auto-correlation sequence is close to discrete impulse, so already the magnitude of the first local maximum different from origin can be used for signal power estimation, see Fig. 5.) Increasing auto-correlation sequence (ACS) variance of the unbiased ACS estimate for delays approaching the sampled signal part length can be clearly observed from Fig. 5. The signal RMS values of both signals and noises are found, and increasing SNR using filtration of noisy signal by a suitable FIR and IIR filter from the previous task is demonstrated and should be explained by students.

Compared to the original version of this task, the standard deviations of additive noises were unified to be 1 for both the normal and the uniform noise. This change took place from our experience that some students came to wrong conclusions concerning the influence of the uniform and normal additive noise caused by the different variances of these noises in the MATLAB default settings in functions “rand” and “randn” that was originally used for noise generation. Students also follow improving the normal and uniform distributions by displaying several histograms of noise for increasing numbers of processed samples. They are also asked to find the noise standard deviation from histograms of the two amplitude distributions and compare them to values found from autocorrelation functions. Figure 5 and 6 are examples of screens in this task.

### III. Conclusion

The above-described changes helped us to increase the usefulness of the original version of our web server application in teaching/learning DSP algorithms covering the described topics. The usefulness of the present version of this DSP teaching tool can be verified easily by anybody after selecting the <http://merux.feld.cvut.cz/> web site.

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