Analysis of Matched Filters in MATLAB Environment

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Abstract – **It's described in the paper a laboratory exercises for the course on Signals and Systems. On the base of the theory of matched filters (MF), the students can made some simulation models for synthesis and analyze of matched filters. The important characteristics can be analyzed in time and spectral domain such as Amplitude/frequency characteristics and Phase/frequency characteristics, correlation function. The simulations are made in MATLAB environment by using of SIMULINK toolbox.**

Keywords – **Signals and systems, matched filters, detection and identifying of signals, computer simulation, MATLAB.**

I. INTRODUCTION

It's described in the paper an idea of exercises for the course on Signals and Systems of students from faculty of communications, from faculty of computer systems and from faculty of electronics.

The matched filters are used by signal processing with background noise. The success of noise processing method depends on its ability to characterize and model the noise process and to use the noise characteristics advantageously to differentiate the signal from the noise. By the matched filters 2 principal criteria are used: maximum of signal-to-noise ratio (SNR) and minimum of mean square error (MSE). Their using in signal processing is appropriated by selectivity, precision of the characteristics and the reliability of the filters.

On the base of the theory of the matched filters, the students can made a simulation model for analyze and synthesis of these filters. Some important characteristics can be analyzed: the spectrum, correlation function.

II. PROBLEM FORMULATION

The optimal filtration on the base of matched filters can be realized by the following conditions:
- The form of the signal and it's power spectrum is known;
- The noise model is additive, with using of Gaussian white noise with power spectrum N_0.

The matched filter is linear filter, which provides maximal signal-to-noise ratio (SNR_{max}).

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The S_{out} can be obtained (Eq.1) [1]:

$$S_{out}(t_0) = \frac{1}{2\pi} \int_{-\infty}^{\infty} |T(\omega)||S_{in}(\omega)|e^{j(\omega t_0 + \varphi_T + \varphi_S)}d\omega \quad (1)$$

The noise dispersion is decribed by (Eq.2):

$$\sigma_{out}^2 = \frac{1}{2\pi} \int_{-\infty}^{\infty} N_0 T^2(\omega)d\omega \quad (2)$$

For SNR_{max} is obtained (Eq.3):

$$SNR_{max} = \frac{\left| \frac{1}{2\pi} \int_{-\infty}^{\infty} |T(\omega)||S_{in}(\omega)|e^{j(\omega t_0 + \varphi_T + \varphi_S)}d\omega \right|}{\sqrt{\frac{N_0}{2\pi} \int_{-\infty}^{\infty} T^2(\omega)d\omega}} \quad (3)$$

According to principles of the matched filtration (Eq.4) [2]:

$$T_{opt}(\omega) = A.S_{in}^*(\omega)e^{-jwt_0} \quad (4)$$

where $S_{in}^*(\omega)$ is the complex conjugateed spectrum of the signal; $A.$ = const.

The transmission gain corresponds to the spectrum form of the input signal S_{in}.

On the base of the theory the students can do the following tasks:
- To design matched filters for following signals: unit regtangular impulse, regtangular pulse train, unit radio impulse, radio impulse train, gaussian impulse, gaussian pulse train;
- To analyze the influence of signal parameters to the output signal and it's spectrum;
- To analyze the correlation functions for the investigated signals.

III. EXPERIMENTAL PART

The design of the MF can be realized in MATLAB environment by using of SIMULINK toolbox [2].

The unit impulse signal is generated by using of block "Step". For investigation of the noise influence can by switched the block "Gaussian noise". So the noise can be added to the unit impulse. The process can be oserved on the Scope. The spectrum of the input and output signals can by observed according to the Power Spectrum Density of the signals.

The simulation model of the MF for unit impulse is given in Fig.1.

To generate pulse train is using the block "Pulse Generator". The occording simulation model for pulse train is given in Fig.2.
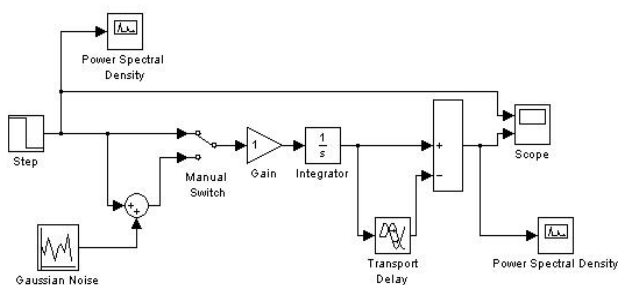
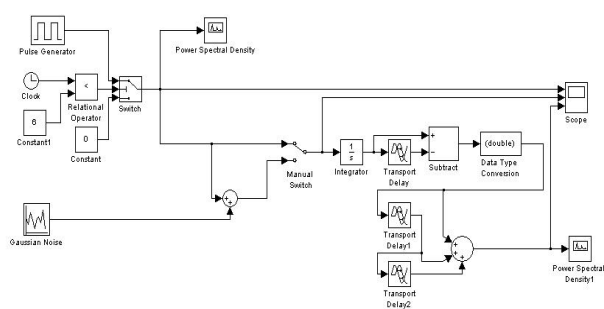Fig.1 Model of MF for unit regtangular impulse

Fig.2 Model of MF for regtangular pulse train

To genetate a unit radio impulse is used block "Sine wave". For time limitation of the signal to one period is used a block "Switch". On its second input can be assigned the number o periods. The simulation model of the MF for unit radio impulse is given in Fig.3.
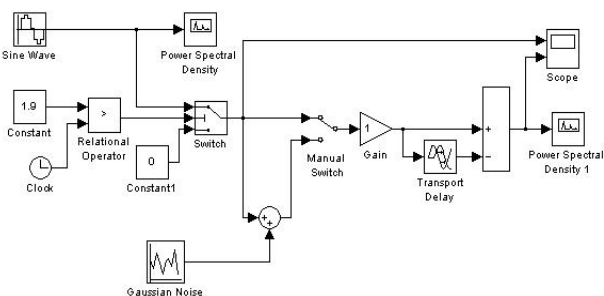

Fig.3 Model of MF for unit radio impulse

In Fig.4 is given a simulation model of MF for unit Gaussian impulse. By using of block "Matlab function" can be generated the Gaussian impulse. The result of the filtration by matched filter for 5 regtangular pulse train is given in Fig.5. It is shown the results of processing in time and in the frequency domain.
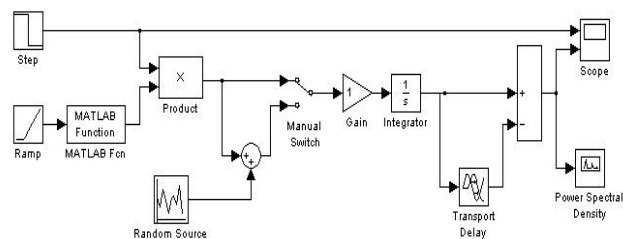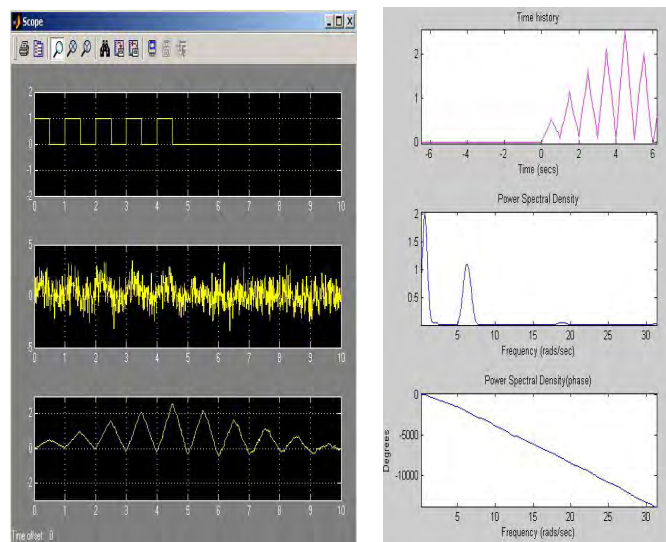

Fig.4 Model of MF for unit Gaussian impulse

Fig.5 Results of the filtration by matched filter for 5 regtangular pulse train in time and frequency domain

IV. CONCLUSION

In the paper are presented the principles to design of matched filters for different signals, which are used by signal processing with background noise.

On the base of the theory of matched filters, the students can create a simulation model for synthesis and analyze of these filters. The signals can be processed and analyzed in time as in frequency domain. The students can create models to generate different signals and to change their parameters. So with the help of simulation they can investigate the influence of the signal parameters by the process of filtration. The method can be developed and the described exercise can be used for web based distance education.

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