

# Spectrum Signal Analysis in MATLAB Environment

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**Abstract** – The spectrum signal analysis is very important in communication. Its basic application is the signal processing, such as filtration, detection and identifying of the different signals on the noise background, bandwidth limitation in the channel. With help of the computer simulation it's made a trial in the paper to illustrate this process by different signals. It can be used by deeper studying the type of spectral characteristics and their properties. The computer simulation is realized in MATLAB environment. The paper can be used in engineering education in studying this process.

**Keywords** – Communication, signal processing, spectrum analyses, detection and identifying of signals,, computer simulation.

## I. INTRODUCTION

The signal analysis in the time domain is not always sufficient. In many practical cases is necessary the complex signal analyses. This includes obligatory analyses in the frequency domain. The goal of spectral estimation is to describe the distribution (over frequency) of the power contained in a signal, based on a finite set of data. The various methods of spectrum estimation available in the signal processing can be categorized as follows: nonparametric methods, parametric methods, subspace methods. Nonparametric methods are those, in which the estimate of the PSD (Power Spectral Density) is made directly from the signal itself [1]. Parametric methods can yield higher resolutions than nonparametric methods in cases, when the signal length is short. These methods use a different approach to spectral estimation; instead of trying to estimate the PSD directly from the data, they model the data as the output of a linear system driven by white noise, and then attempt to estimate the parameters of that linear system. The most commonly used linear system model is the all-pole model, a filter with all of its zeroes at the origin in the z-plane. The output of such a filter for white noise input is an autoregressive (AR) process. For this reason, these methods are sometimes referred to as AR methods of spectral estimation [1].

Subspace methods, also known as high-resolution methods or super-resolution methods, generate frequency component estimates for a signal based on an eigenanalysis or eigendecomposition of the correlation matrix [1].

The most popular are the nonparametric methods. Their priorities over the others are: good computing efficiency (based on FFT) and the spectra estimation is proportional to the power of the input signal harmonic components. The failings are: the frequency resolution is dependent from the size of the segment and not from the type of the input signal; there is 'dilute' of the spectral maximums and this method can be used to not numerous input discrete. But they can be successful used by many signals.

At the university level, the material studied becomes more abstract and more mathematical. The students need to become a deeper insight of the practical application of the most popular methods. It's described in the paper a laboratory exercises for the undergraduate course on Signals and Systems of students from faculty of communications and from faculty of computer systems.

The computer simulation can be realized in the program environment of MATLAB with using the system for visual modelling SIMULINK. In this case, the spectrum analysis is based on the nonparametric methods.

## II. PROBLEM FORMULATION

The problem on spectrum signal analysis can be presented with following features:

- There 2 type of signals: analogue and discrete (periodic and aperiodic) signals. The signals can have different forms such as rectangular, triangular, saw-tooth, exponential, Gaussian, arbitrarily. Their parameters can be determinate by the students.

- Let  $S(t)$  is an aperiodic analogue signal, it has the following CFT, given in Eq.1 [3]:

$$G(\omega) = \int_{-\infty}^{\infty} S(t)e^{-j\omega t} dt \quad (1)$$

where  $G(\omega)$  is the Fourier Spectral Density. In general case, it's a complex function, described with Eq.2[3].

$$G(\omega) = \text{Re}[G(\omega)] + j \text{Im}[G(\omega)] = |G(\omega)|e^{j\varphi(\omega)} \quad (2)$$

where  $|G(\omega)|$  is the Amplitude Fourier Spectrum,  $\varphi(\omega)$  is Phase Fourier Spectrum and  $|G(\omega)|^2$  is the Power spectrum of the signal  $S(t)$ .

In case of the discrete signal  $S(n\Delta t)$ , DFT must be used, given in Eq.3 [3].

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$$G[k] = \sum_n^{N-1} S[n] e^{j2\pi k n / N}, k \in [-N/2, N/2-1] \quad (3)$$

and  $|G(k)|^2$  is the discrete Power Spectrum.

So on base of computer simulation we can formulate following problems:

1. To create a model, which can be used by generating of different signals and estimating its spectrum
2. To analyze the properties of the spectrum functions by the definite signals
3. To investigate the influence of the signal form on the spectrum

By the simulation we need to see the going processes. The characteristics can be given in graphical mode.

### III. EXPERIMENTAL PART

The formulated problems are solved by computer simulation in MATLAB, version 6.5 environment with using the SIMULINK TOOLBOX.

This can provide direct access to the basic possibilities of the program environment. On the other side, models can be created by the students without experience in using of the other programming tools. It's may be a great priority, because visual presentation of the fulfillment simulation can be realized. SIMULINK possesses an intuitive easy graphical interface. This method gives better results, it's precisely and we can see the computed functions direct in graphical mode. For a model creating are used direct the existing in SIMULINK blocks for PSD [2].

To generate the analogue signals with different forms such as rectangular, triangular, saw-tooth, exponential and Gaussian, the students can use the following blocks: 'Ramp', 'Step', 'Repeating Sequence', 'Fcn', 'MATLAB Function', 'Product', 'Pulse Generator'. By giving parts of the periodic triangular, saw-tooth and sinusoidal signals, can be separated only parts of them, for example for one half of period. This can be made by multiplication with suitable tuning of "Pulse Generator" on amplitude.

The exponential and Gaussian signals can be generated in 2 ways: First as detached program, this can be m-file, kept in MATLAB work environment. It can be used by control of the block 'MATLAB Function'. The priority in this case is that the time intervals for the signal changes can be given beforehand. The second way is by description of the signal in block 'Fcn'. The signal is not limited in this case and can be made by block "Ramp". The second way is better of two reasons:

- 'Fcn' works rusher than 'MATLAB Function'
- Signal parameters can be changed easier with the goal to investigate their influence to the spectrum

The running time can be set in constant or variable step. The students can observe a running process by the block 'Scope', which is included in the model, too.

An example for a simulated model is given in Fig.1. It's generated a following signal, given in Eq.4 :

$$S(t) = \begin{cases} \frac{2a}{T}t + a, & -T/2 \leq t \leq 0 \\ -\frac{2a}{T}t + a, & 0 \leq t \leq T/2 \end{cases} \quad (4)$$

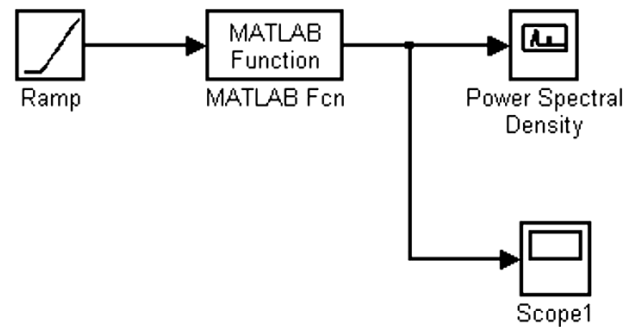


Fig.1. Signal generating model

In Fig.2 we can see the signal in the time and frequency domain, too.

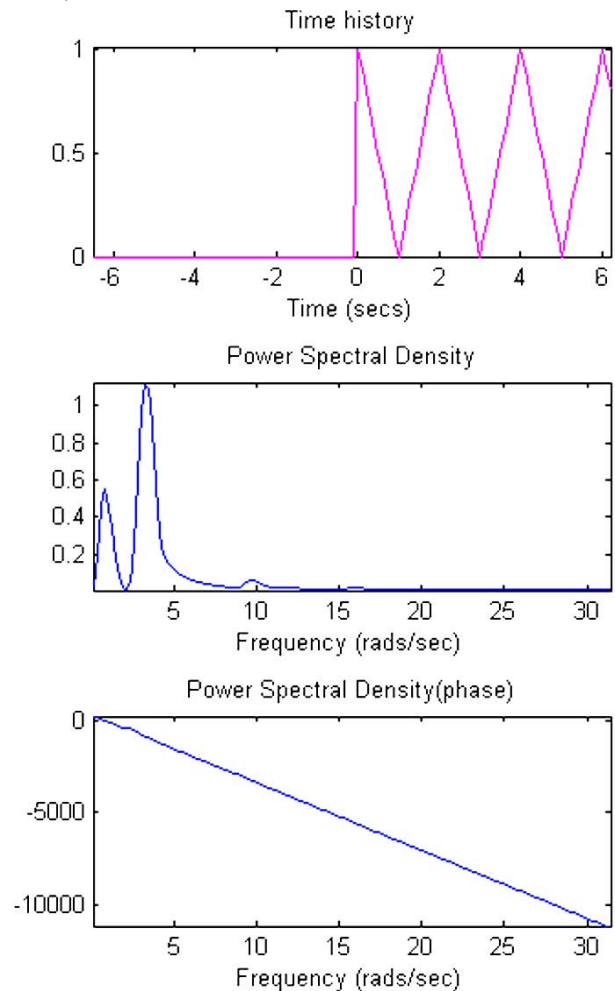


Fig.2. Generated signal

By using of blocks 'Derivative' and 'Integrator' it's made possible to investigate their influence to the spectrum of the signal, given in Fig. 3 and Fig.4

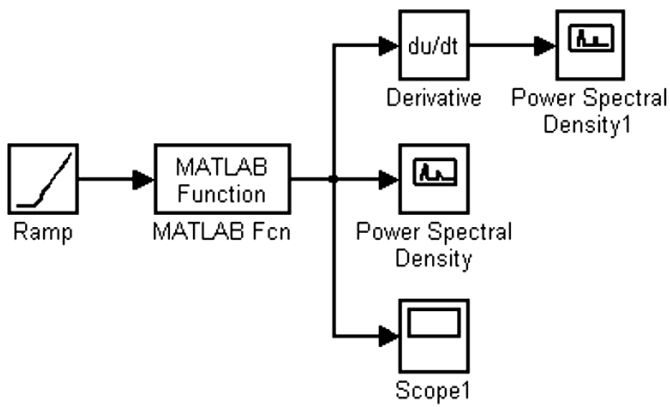


Fig.3. Model for spectrum analysis of integrated signal

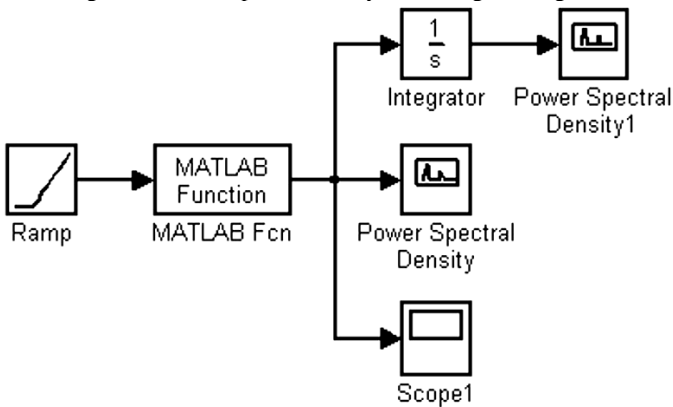


Fig.4. Model for spectrum analysis of derivative signal

#### IV.CONCLUSION

The spectrum signal analysis is one of the very important problems in the theory of the signals. It's made a trial in the paper to present the possibility of the computer simulation in MATLAB environment to get deeper insight on studying the spectral functions, their properties in case of analogue and discrete signals. The students can create models to generate different signals and to change their parameters. They can also generate models to compute the spectral functions. So with the help of simulation they can investigate the influence of the signal parameters on the PSD. The method can be developed and the described exercise can be used for web based distance education.

#### REFERENCES

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