Studying on Frequency Modulation in MATLAB Environment

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***Abstract* – Frequency Modulation (FM) is widely used in communication systems. FM is used at VHF radio frequencies for high-fidelity broadcasts of music and speech. A narrowband form is used for voice communications in radio settings. It's made a trial in the paper to present the possibility of the computer simulation in MATLAB environment by deeper studying and analyzing the effect of various factors such as modulations index, the form and amplitude of the modulating signal on the spectrum and spectrum band of the modulated signals.The paper can be used in engineering education in studying this process.**

***Keywords* – Frequency modulation, communication systems, modulations index, narrowband FM, wideband FM, computer simulation.**

I. INTRODUCTION

At the university level, the material studied becomes more abstract and more mathematical. It's described in the paper a laboratory exercises for the course on Signals and Systems of students from faculty of communications and from faculty of computer systems.

FM is a form of modulation which represents information as variations in the instantaneous frequency of carrier wave. On the base of theory of the process, with help of computer simulation, the students get deeper insight of effect of various factors such as modulations index, the form and amplitude of the modulating signal. They can investigate their influence on the power spectral density and bandwidth of the modulated signals.

The computer simulation can be realized in the program environment of MATLAB with using the system for visual modelling SIMULINK. A model can be created, which generate the analysed signals and functions. There are 2 methods to create a model in SIMULINK. First it's can be used mathematical formulae for creating building blocks, [1] and second by direct using of blocks for the investigated process [4,5,6,7]. By generation in case of analogue signals can be used functions or blocks from SIMULINK [2]. Digital data can be represented by shifting the carrier frequency among a set of discrete values, a technique known as frequency-shift keying. A program can be made in case of digital signals, so the signals can be choose from the students.

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II. PROBLEM FORMULATION

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

- There are 3 kinds of signal in case of FM process: modulating, carrier and FM modulated signal.
- The analogue modulating signals can have different forms such as sinusoidal, rectangular, triangular, saw-tooth, Gaussian. Their parameters can be determinate by the students. Digital signals and their parameters can be determinate totally from the students.
- The sinusoidal signal can be used as carrier.

The mathematical description for the modulated signal is given in Eq.1

$$a_{FM}(t) = A_0 \cos \psi_{FM}(t) = \\ = A_0 \cos(\omega_0 t + m_\omega \sin \Omega t) \quad (1)$$

where m_ω is the modulation index.

This indicates by how much the modulated variable varies around its unmodulated level. In this case, for FM, it relates to the variations in the frequency of the carrier signal. The modulation index m_ω is depended from the frequency of the modulating signal (Eq.2):

$$m_\omega = \frac{\Delta\omega_m}{\Omega} \quad (2)$$

If $m_\omega << 1$, the modulation is called narrowband FM, and it's bandwidth is approximately 2Ω.

If $m_\omega >> 1$, the modulation is called wideband FM, and it's bandwidth is approximately $2\Delta\omega_m$.

- The frequency spectrum of an actual FM signal has components extending out to infinite frequency, although they become negligibly small beyond a point.

For a simplified case, the harmonic distribution of a sine wave signal modulated by another sine wave signal can be represented with Bessel functions – this provides a basis for a mathematical understanding of frequency modulation in the frequency domain.

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

1. To create a model of FM modulation process in case of $m_\omega << 1$ and in case of $m_\omega >> 1$.
2. To analyze the influence of the form of the modulating signal on the power spectral density.
3. To investigate the influence of the modulations index of the spectrum and bandwidth of the modulated signal.

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 with using the SIMULINK TOOLBOX [3].

For a model creating are used mathematical formulae for creating building blocks. To generate the analogue signals with different forms such as, sinusoidal, rectangular, triangular, saw-tooth, and Gaussian, the students can use the following blocks: 'Signal Generator', 'Ramp', 'Step', 'Repeating Sequence', 'MATLAB Function', 'Product'. The using blocks can be connected in the model informative and by the control, too. The type of the connection is dependent on the block and on the logic of his work. 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. They can see the spectrum of the FM signals by the 'Spectrum Scope'. An example for a simulated model is given in Fig.1.

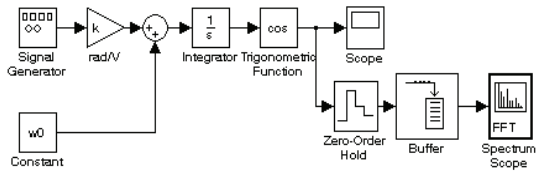

Fig.1 Model for FM process

Fig.2 presents in graphical mode the FM signal. It's generated a saw-tooth as modulating signal for FM. The following parameters are choosen: A_M=1V; A_0=1V; F_M= 100 Hz; f_0= 2000 Hz; K=5000.

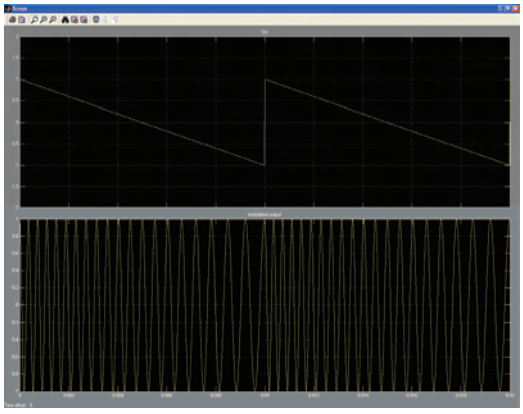

Fig.2 Modulating and modulated signals by FM

The power spectral density of this FM signal is given in Fig.3. It's shown, that the bandwidth of the FM signals, independent of the form of modulating signal.

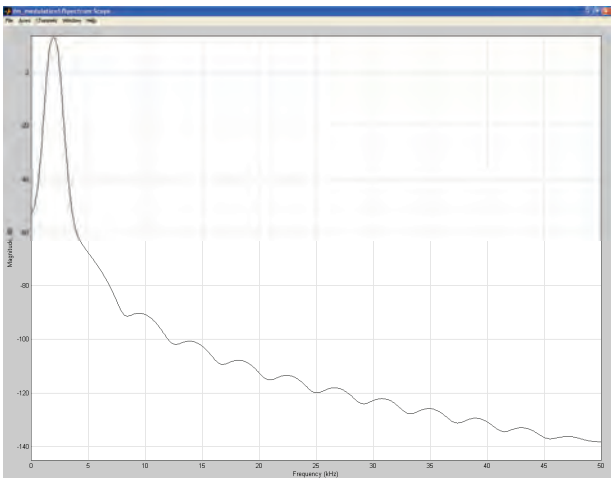

Fig.3. Power Spectral Density of FM signal by $m_\omega >> 1$

IV.CONCLUSION

The frequency modulation 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 this process, on effect of various factors such as modulations index, the form and amplitude of the modulating signal. It's helpful for the students to create models to generate different signals and to change their parameters. So with the help of the simulation they can investigate the influence of the signal parameters on the FM frequency band and the spectrum type, and observe the running processes in the time domain, too.

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