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MODELING AND SIMULATION OF ANALOG AMPLITUDE AND PULSE-AMPLITUDE MODULATION AND DEMODULATION MEASUREMENT TRANSDUCERS

The modulation and demodulation measurement transducers, also known as modulators and demodulators, are used in measurement devices in case of transmission of measurement information in the form of data for the results from the measurement process or exchanging control commands between controllers, intelligent sensors and measurement devices, which have computer interface. That group of devices contains also the analogue amplitude and pulse-amplitude modulators and demodulators. In this paper are proposed simulation models of amplitude and pulse-amplitude modulators and demodulators, based on mathematical models related to the operation of this type of measurement transducers and by using the computing capabilities of the Matlab software and Simulink in particular. Such modulators and demodulators simulations model can successfully be used in the training of PhD students and students for the purpose of research, analysis and visualising characteristics of the measurement transducers.

Keywords: *standard amplitude modulation, standard amplitude demodulation, pulse amplitude modulation, pulse amplitude demodulation, Matlab model, Simulink model.*

Introduction

The measurement transducers are devices that convert one type of input value to another type of output value by certain rule and with some accuracy. There are different classifications of the measurement transducers [1]. Most often they are divided by the type of input and output to analogue and digital transducers. According to the relationship between input and output values, i.e. the function of conversion, they are divided into linear and nonlinear transducers. In most cases the desired function of conversion is linear, but there are cases where the nonlinear function is desirable, e.g. square, exponential or logarithmic function and so on. In these cases the measurement transducers are known as functional transducers.

Special group of linear measurement transducers are the modulating transducers. They are characterized by the interaction of input signal $x(t)$ also known as modulating signal and the carrier signal $y_C(t)$. Typically the carrier signal is sinusoid waveform, but often for a carrier signal a single polar or a double polar pulse signal (square wave pulse train) is used. In these cases the modulating transducers are called pulse transducers. As a result of interaction between $x(t)$ and $y_C(t)$ the output modulated signal $y_M(t)$ is formed. The input signal is modulating one of the three parameters of the carrier signal – amplitude, frequency and phase. They correspond to the main three types of modulation: amplitude, frequency and phase.

If the carrier signal is sinusoidal:

$$y_C(t) = Y_m \sin \omega_0 t\,, \tag{1}$$

then the modulated signal [1] is

$$\begin{aligned} y_M(t) &= \left[Y_M + k_{AM} x(t)\right] \sin \omega_0 t = \\ &= y_C(t) + \frac{k_{AM}}{Y_m} x(t) y_C(t), \end{aligned} \tag{2}$$

where K_{AM} is conversion factor.

Transducers, which implement (2) are known as amplitude modulators (AM). There are amplitude modulators, which implement only the second term of equation (2). They are called balanced amplitude modulators (BAM).

From equation (2) follows that in order to build a model of an amplitude modulator it is enough to implement the mathematical operations multiplication and summation. A model structural diagram of the amplitude and the balanced amplitude modulator model is shown in fig. 1.

The demodulation of the modulated signal $y_M(t)$ is made by rectifying and filtering or by division or multiplication of the carrier signal $y_C(t)$ [1].

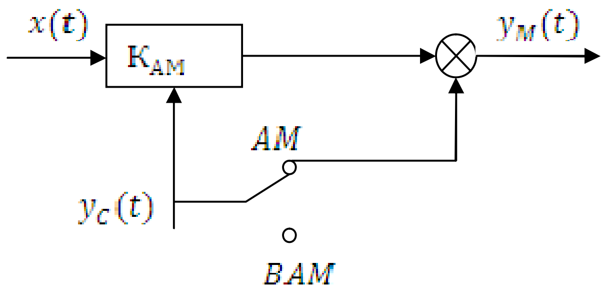

Fig. 1. Model structural diagram of the amplitude and the balanced amplitude modulator

1. Building a simulation model of an amplitude modulator and a demodulator by means a Simulink and Matlab

One of the mostly used software means for modelling and simulating of systems and processes is the Matlab program package [2 – 4]. It offers a convenient and an easy to use development kit for programming, computing and visualisation. It is based on module principle as the individual modules (toolboxes) are a set of ready to use specialized functions recorded as M-files.

The software modeling of modulated signals by means of Matlab is available with the help of a built-in function "**modulate**" in Signal Processing Toolbox, which has the following syntax [4, 5]:

y=modulate(x,fc,fs,*'method'*) (3)

and

y=modulate(x,fc,fs,*'method'*,opt). (4)

Here the function "**modulate**" is applied to the real message signal x with a carrier frequency **fc** and sampling frequency **fs**, using one of the options for ***'method'*** which corresponds to the type of modulation. Some methods accept an option, opt. For example, for amplitude modulation the syntax is

y=modulate(x,fc,fs,*'am'*). (5)

Software modeling of demodulated signals is possible by means of Matlab tools too. The built-in in Signal Processing Toolbox demodulate function is used in this case. It is with the following syntax [4, 6]:

y=demod(x,fc,fs,*'method'*) (6)

and

y=demod(x,fc,fs,*'method'*,opt). (7)

This approach to the software modeling of modulated and demodulated signals is very convenient, but it can't be used for the purposes of research and analysis of modulators and demodulators, because it can't reflect to the hardware features, changes of coefficient of modulation type of modulating signal. These drawbacks can be overcome by creating a simulation model in Simulink graphical environment of Matlab, where graphical functional blocks are used.

In certain cases from methodological point of view is appropriate to develop a program in Matlab in which can be set form and values of the parameters of input and carrier signals. Such Matlab program is shown in [7].

Basic part of the Matlab package is the Simulink graphic environment, offering object oriented programming by the use of graphic functional blocks.

Using the standard Simulink library and following the structural diagram in fig.1, a simulation model of an amplitude modulator could be built, as shown in fig. 2.

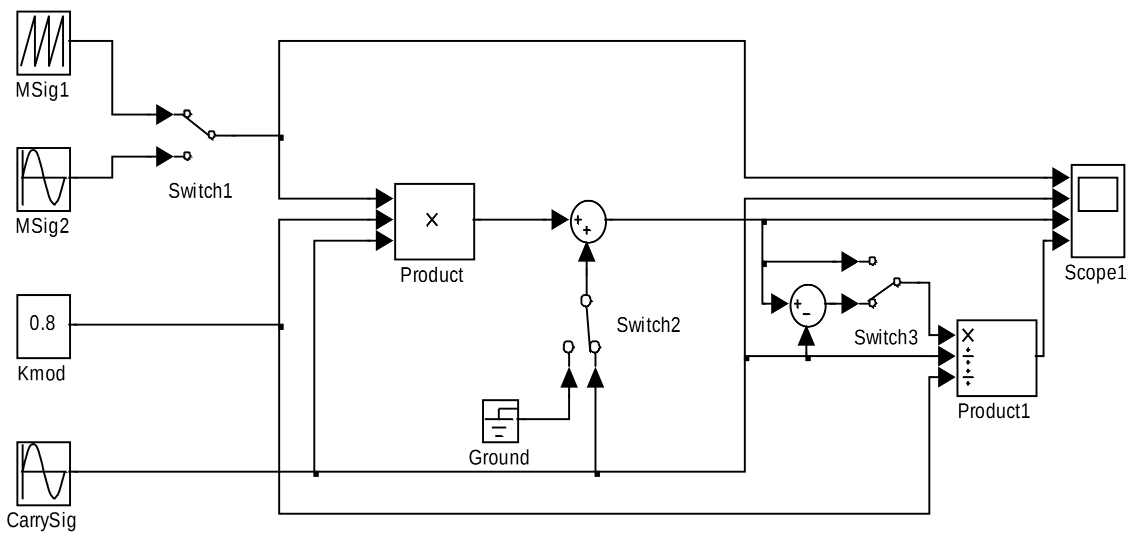

Fig. 2. Simulink model of an amplitude modulator and amplitude demodulator

The Msig1 and Msig2 blocks are used for generating different types of modulating signals using Switch1. To generate a carrier signal is used CarriSig block. A multiplication of the modulating and the carrier signals is performed by the Product block with reverse ratio of transformation, as its value is introduced by the Kmod block. The simulation model proposed can work in amplitude modulator mode and in balanced amplitude modulator mode, as these modes are respectively chosen by Switch2 and a sum block. In such a way the simulation model of the demodulation transducer is accomplished in this case by the Product1 block and the Sum block. The modulating, carrier, modulated and demodulated signals are represented graphically as shown on fig. 3 for standard and on fig. 4 for balanced types of AM modulations and AM demodulations.

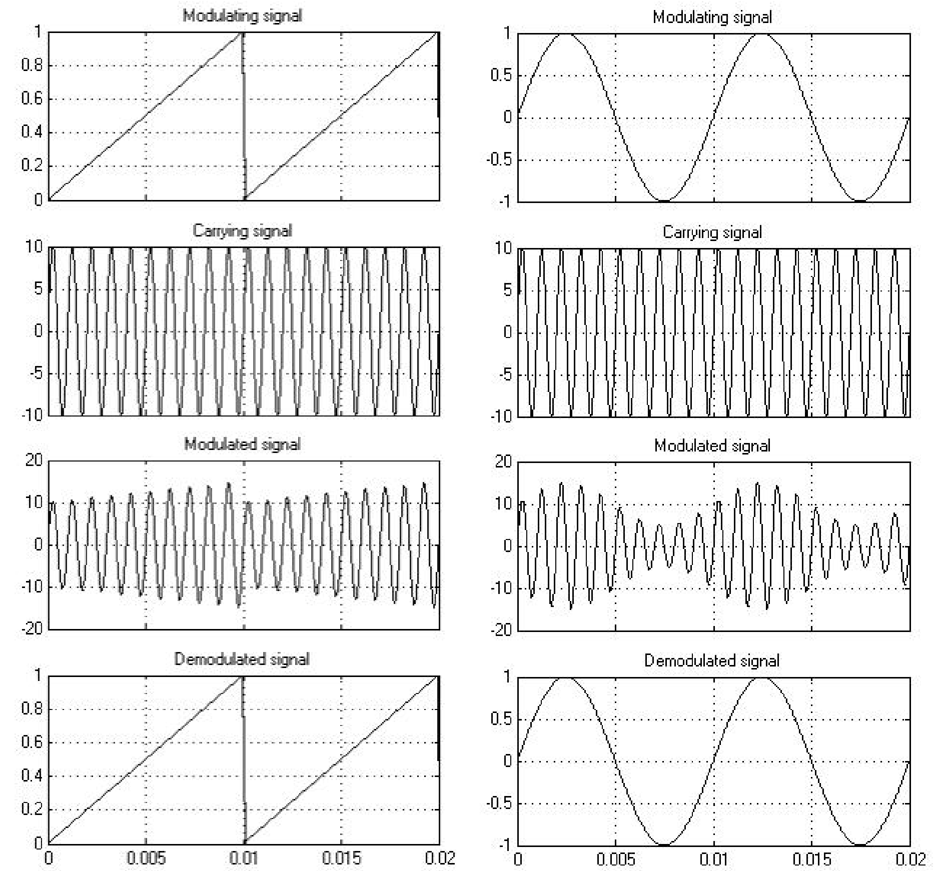

Fig. 3. Modulating, carrier, standard AM modulated and AM demodulated signals

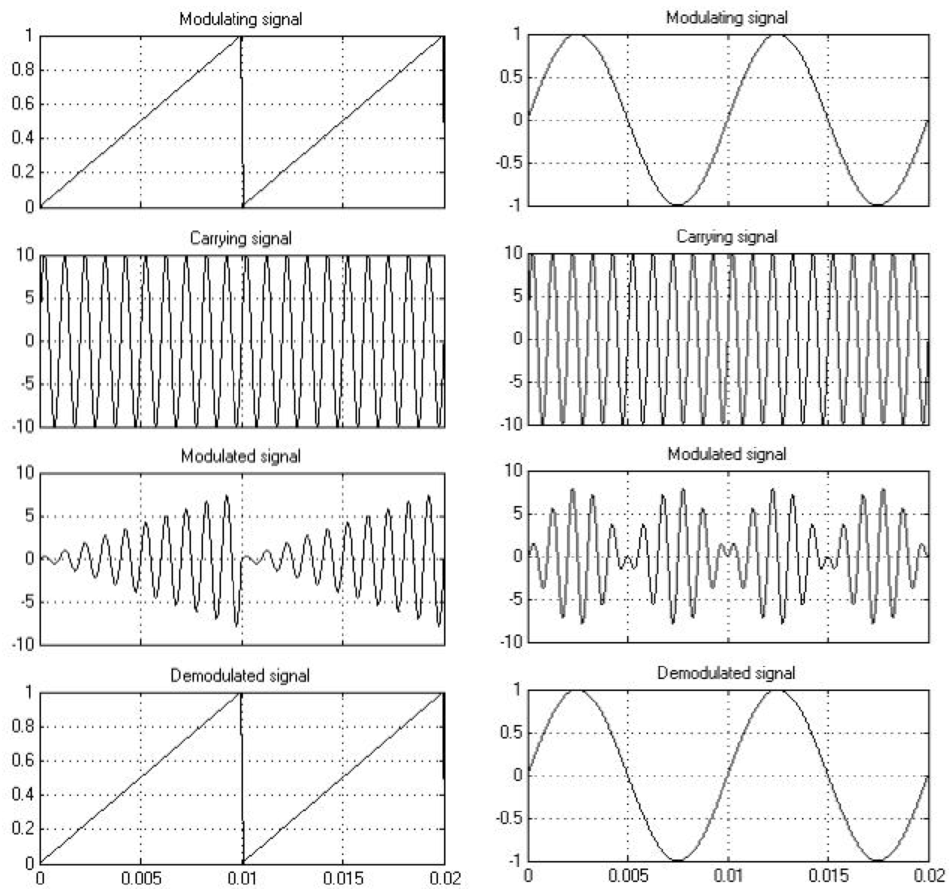

Fig. 4. Modulating, carrier, balanced AM modulated and AM demodulated signals

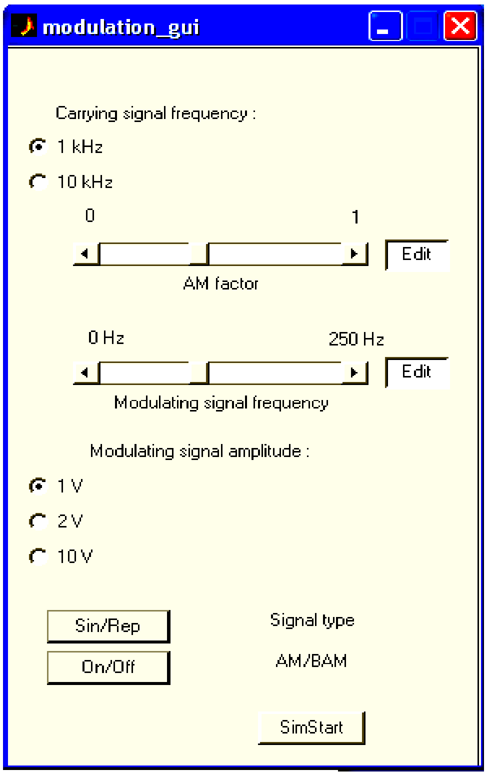

Fig. 5. Graphic user interface

2. Building a graphic user interface of an amplitude modulator simulation model by means of Matlab

Another useful applicable Matlab package is the Guide environment, which purpose is to build a graphic user interface (GUI) which can assist the interactive work with the Simulink model. Using GUI the user can initialize and change simulation parameters, as well as parameters of certain Simulink blocks. In fig. 5 is shown the graphic user interface GUI.

The following steps are fulfilled for the realization of GUI:

- Define the elements of GUI: the number and type of managing parameters and their values are set.
- Perform GUI: the elements are grouped in a suitable manner so as to make easy for the user to intercept the information.
- Programme GUI: based on the designed GUI, M-file is generated containing Matlab functions necessary for visualising its elements.

3. Simulation model of pulse-amplitude modulator and demodulator

The simulation model of pulse-amplitude modulator and demodulator is shown in fig. 6. It is constructed using again the model shown in fig. 1. The only difference is the type of the carrier signal, which in this case is a single polar square signal

$$y_C(t) = \begin{cases} Y_m & \text{for} \quad t \in kT_0, kT_0 + T_P; \\ 0 & \text{for} \quad t \in kT_0 + T_P, (k+1)T_0, \end{cases} \tag{8}$$

where T_0 is the period, and T_P is the duration of the rectangular pulse signal.

The modulating, carrier and modulated signals are shown by Scope block in fig. 7 for standard and on fig. 8 for balanced types of PAM modulations and PAM demodulations.

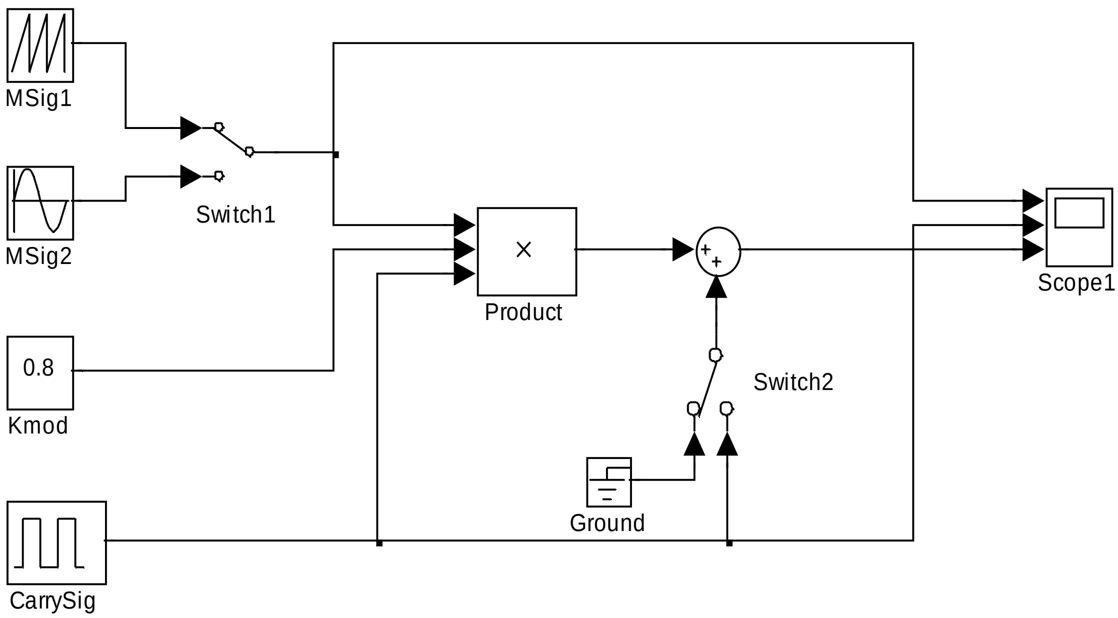

Fig. 6. Simulink model of an pulse amplitude modulator and pulse amplitude demodulator

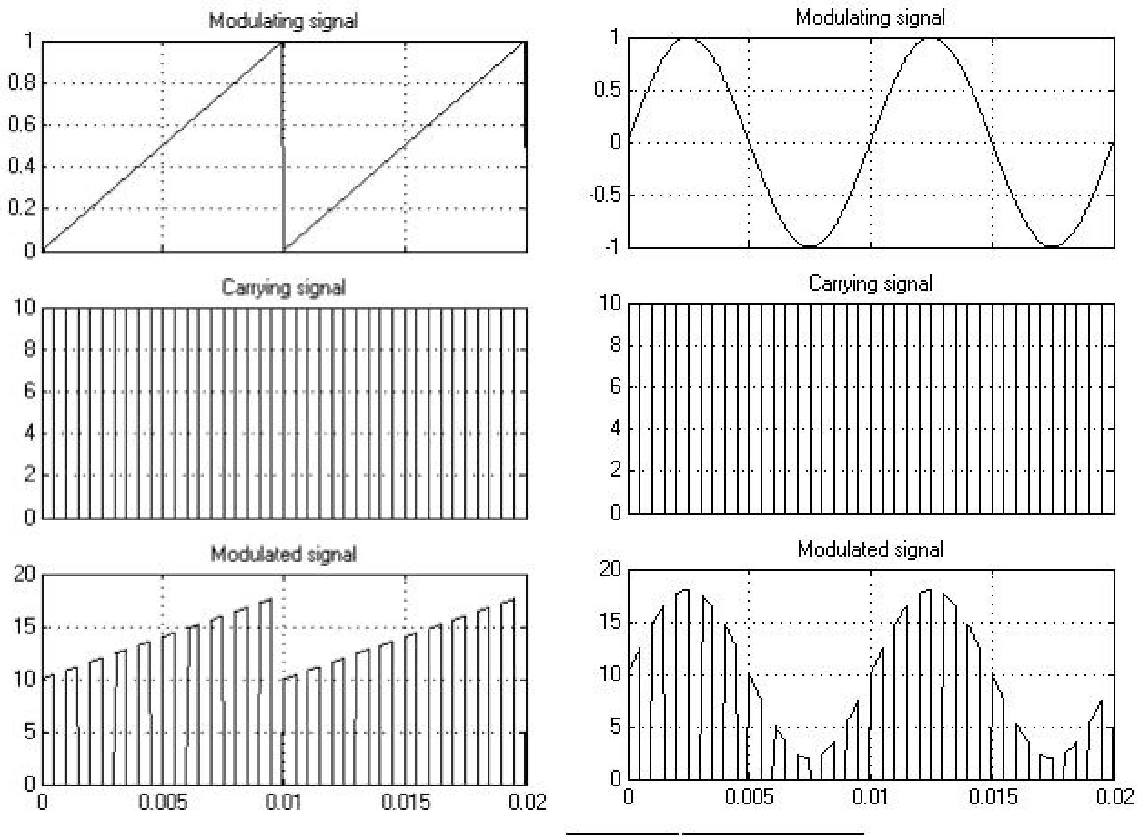

Fig. 7. Modulating, carrier, standard PAM modulated and PAM demodulated signals

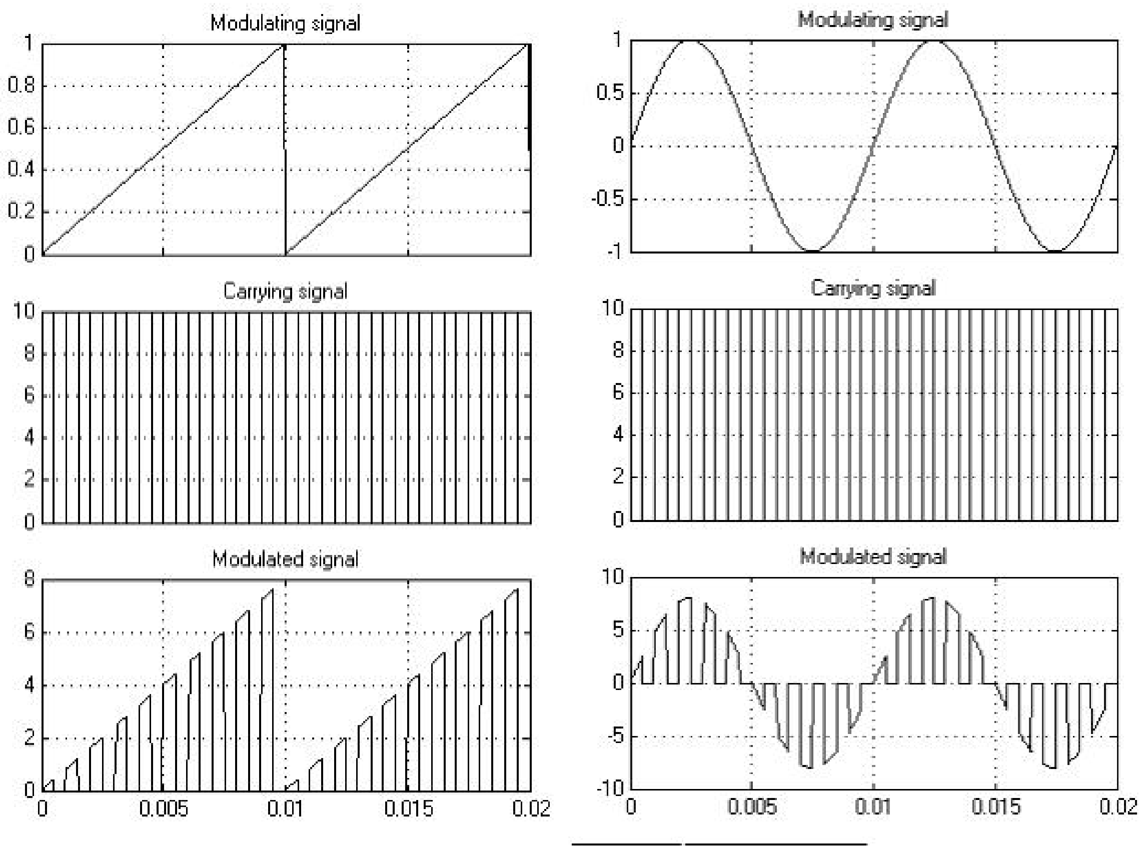

Fig. 8. Modulating, carrier, balanced PAM modulated and PAM demodulated signals

Conclusion

The simulating models of amplitude and pulse-amplitude modulators and demodulators presented can successfully illustrate the operation and capabilities of these types of measurement transducers.

Based on the models proposed research and analysis work of metrological characteristics can be carried out, necessary at the stage of engineering and especially in training PhDs and university students.

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МОДЕЛЮВАННЯ ТА ІМІТАЦІЯ АНАЛОГОВОЇ АМПЛІТУДИ ТА АМПЛІТУДНО-ІМПУЛЬСНОЇ МОДУЛЯЦІЇ ТА ДЕМОДУЛЯЦІЇ ВИМІРЮВАЛЬНИХ ПЕРЕТВОРЮВАЧІВ

П. Цвєтков

Вимірювальні перетворювачі модуляції і демодуляції, відомі також як модулятори і демодулятори, використовуються у вимірювальних приладах для передачі вимірювальної інформації у вигляді даних для результатів вимірювального процесу або обміну команд управління між контролерами, інтелектуальними датчиками і вимірювальними приладами, що мають комп'ютерний інтерфейс. Ця група пристроїв містить також аналогові амплітудні та амплітудно-імпульсні модулятори і демодулятори. У даній роботі пропонуються імітаційні моделі амплітудних і амплітудно-імпульсних модуляторів і демодуляторів, які засновані на математичних моделях, що пов'язані з експлуатацією даного типу вимірювальних перетворювачів і використанні обчислювальних можливостей програмного забезпечення Matlab і, зокрема, Simulink. Такі імітаційні моделі модуляторів і демодуляторів можуть успішно використовуватися при підготовці аспірантів і студентів з метою проведення досліджень, аналізу та візуалізації характеристик вимірювальних перетворювачів

Ключові слова: *стандартна амплітудна модуляція, стандартна амплітуда демодуляції, амплітудно-імпульсна модуляція, амплітуда імпульсу демодуляції, модель Matlab, модель Simulink.*

МОДЕЛИРОВАНИЕ И ИМИТАЦИЯ АНАЛОГОВОЙ АМПЛИТУДЫ И АМПЛИТУДНО-ИМПУЛЬСНОЙ МОДУЛЯЦИИ И ДЕМОДУЛЯЦИИ ИЗМЕРИТЕЛЬНЫХ ПРЕОБРАЗОВАТЕЛЕЙ

П. Цветков

Измерительные преобразователи модуляции и демодуляции, известные также как модуляторы и демодуляторы, используются в измерительных приборах для передачи измерительной информации в виде данных для результатов измерительного процесса или обмена команд управления между контроллерами, интеллектуальными датчиками и измерительными приборами, имеющими компьютерный интерфейс. Эта группа устройств содержит также аналоговые амплитудные и амплитудно-импульсные модуляторы и демодуляторы. В данной работе предлагаются имитационные модели амплитудных и амплитудно-импульсных модуляторов и демодуляторов, основанные на математических моделях, связанных с эксплуатацией данного типа измерительных преобразователей и использовании вычислительных возможностей программного обеспечения Matlab и, в частности, Simulink. Такие имитационные модели модуляторов и демодуляторов могут успешно использоваться при подготовке аспирантов и студентов для целей проведения исследований, анализа и визуализации характеристик измерительных преобразователей.

Ключевые слова: *стандартная амплитудная модуляция, стандартная амплитуда демодуляции, амплитудно-импульсная модуляция, амплитуда импульса демодуляции, модель Matlab, модель Simulink.*