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Computer Simulation of Complex Electronic Systems of Navigation Systems

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Abstract. The paper proposes ways to reduce the time and improve the quality of development of electronic equipment using computer simulation. The paper considers an example of the development and debugging of a radio-electronic module, which has found its direct application in a local navigation system that operates on the basis of the method of point landmarks. The paper considers a hardware-software complex for the implementation of the study of the health of both individual functional units and radio rangefinder equipment as a whole, as well as for the modernization of the radio-electronic module of the navigation system. The various computer simulation environments available today allow the development and design of electronic equipment at various levels. In the proposed work, computer simulation was carried out in MATLAB / Simulink, LabVIEW, Multisim and MicroCap. The work also provided for the possibility of using data collection and processing modules, which provides the opportunity in one software development and modeling environment to compare the results obtained using simulation modeling and physical research of the object. The result of the work is a hardware-software kit of the radio-electronic module of the navigation system through which it is possible to evaluate the influence of various external influences on the accuracy of determining the range from the interrogator (moving object) to the transponder (stationary beacon).

1 Introduction

The development of electronic systems and devices of various levels of complexity is a multi-stage complex process that requires large expenditures of time, financial and human resources.

In the framework of the work performed, the hardware-software complex is a simulation model of the radio-electronic module (SEM) of the navigation system (NS), considered both at the system and circuit design levels.

The proposed approach is the creation of software and hardware complexes of complex electronic equipment using simulation modeling. Today, in the framework of the dynamically developing world of computer technology and market for electronic

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components, it is relevant because it can significantly simplify the design of complex electronic systems and allow you to visualize the processes that occur in all functional units of electronic equipment.

One of the tasks is to create a hardware-software complex of the radio-electronic module of the navigation system.

A hardware-software complex is a set of hardware and software tools that work together to perform one or more similar tasks.

2 Article text (Article body)

As part of this work, the creation of a hardware-software complex of a radio-electronic module, which underlies the radio-technical local navigation system from the automatic landing system, is considered.

The principle of operation of the RTSLN is based on measuring navigation parameters using the method of point landmarks, i.e. by measuring distances from the on-board electronic interrogator module to ground-based radio beacons (SEM transponders), it is possible to determine the coordinates of an aircraft (A) taking into account information about the coordinates of ground-based radio beacons (RB).

The development of a hardware-software complex includes: phased construction of a simulation model of a radio-electronic module of various design levels; integration of elements of the simulation model from one computer modeling environment to another. Also, the hardware-software complex provides the opportunity to use the interaction of the simulation model with both test equipment and a real device under various operating conditions.

The hardware-software complex was built taking into account the tasks of research and modernization of the radio-electronic module of the navigation system (SEM). The software implementation uses the concept of a distributed solution in which each block of a real complex can be represented as a macromodel implemented in the LabVIEW environment, a circuitry solution implemented in the Multisim environment, or as a set of experimental implementations obtained using data acquisition and processing devices implemented in the LabVIEW environment.

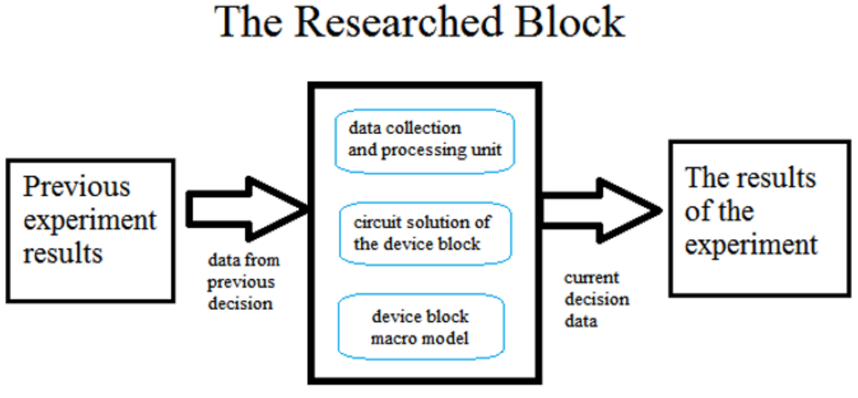


Fig. 1. The principle of building a simulation model.

Designing at the macromodel level is the definition of a specific structural implementation of the radio range-measuring equipment, the interaction of the functional units of the electronic device with each other - i.e. Connections between modules are defined. Design at this level consists of determining the structure of the electronic device, and then determining the optimal values of the structure parameters of this device. All functional blocks at the design level of the macromodel are considered as signal converters, regardless of their internal structure.

In turn, at the circuitry level of creating the simulation model, a detailed design of the internal structure of all functional units of the radio range-measuring equipment is carried out.

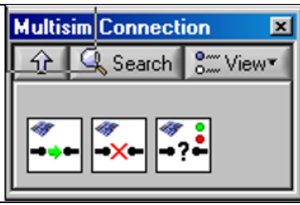
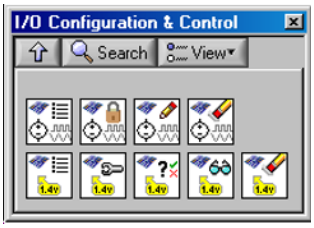
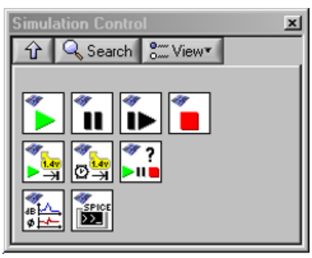
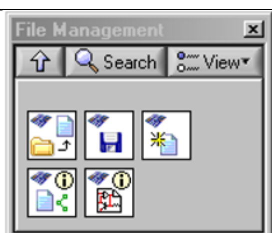
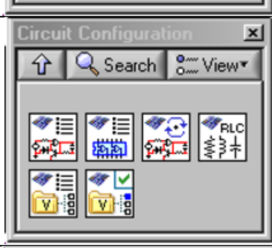
The data obtained as a result of the solution is saved on disk as files of the lvm format, which is widely used in modeling environments such as LabVIEW and Multisim. This approach, from the experience of the authors, can reduce the time for analysis of a specific functional unit of the SEM, carried out without changing the parameters of other modules of the device. Files of the same format are used both to represent the solution of the model and to solve the process of experimental analysis of the operation of the SEM functional block.

The solution for integrating Multisim and LabVIEW 2012 is implemented using the Multisim Automation with the LabVIEW Multisim Connectivity Toolkit add-on, and experimental data is obtained using the PXI Express RF platform.

Multisim API allows you to: open and close existing schema files; form separately and use ready-made signals for current and voltage sources; start, stop and pause the modeling process; get calculation results in nodes where Multisim (Probe) probes are installed; replace Multisim components with other components from the Multisim database; read and set the values of resistors, capacitors and inductances; create reports on the composition of the scheme, receive a listing of the components of the scheme, including the cost of materials and a list of connections; create a schematic image file.

All components for working with Multisim are shown in Table 1.

Table 1. Components for working with Multisim.

Components for working with Multisim	Functionality	Description
	**Multisim Connection** • Multisim Connect.vi • Multisim Is Connected.vi • Multisim Disconnect.vi	These components allow you to connect / disconnect to Multisim
	**I/O Configuration & Control** • Multisim Enum Inputs.vi • Multisim Reserve Input.vi • Multisim Set Input Data.vi • Multisim Clear Input Data.vi • Multisim Enum Outputs.vi • Multisim Set Output Request.vi • Multisim Output Ready.vi • Multisim Get Output Data.vi • Multisim Clear Output Request.vi	I / O components. They allow you to read, set and clear data for inputs and outputs.
	**Simulation Control** • Multisim Run Simulation.vi • Multisim Pause Simulation.vi • Multisim Resume Simulation.vi • Multisim Stop Simulation.vi • Multisim Run Simulation Until Next Output.vi • Multisim Wait For Next Output.vi • Multisim Simulation State.vi • Multisim Do AC Sweep.vi • Multisim Do Command Line.vi	Components that allow you to control the calculation process (start, pause, etc.)
	**File Management** • Multisim Open File.vi • Multisim Save.vi • Multisim New File.vi • Multisim File Name.vi • Multisim Circuit Name.vi	Components that allow you to open, save, create files
	**Circuit Configuration** • Multisim Enum Components.vi • Multisim Enum Sections.vi • Multisim Replace Component.vi • Multisim Enum Variants.vi • Multisim Active Variant.vi	Components that allow you to change the parameters of circuit components
	**Error & Utility** • Multisim Last Error Message.vi • Multisim Log File.vi • Multisim Report.vi • Multisim Version Info.vi • Multisim Path.vi • Multisim Register Stop Event.vi • Multisim Get Circuit Image.vi	Components for Handling Errors and Other Multisim API Utilities

A fragment of the front panel of the software solution is shown in Fig. 2

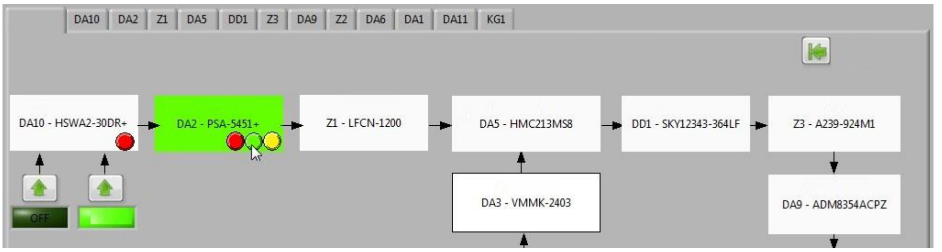


Fig. 2. Receiving path software solution.

For any calculation sequence, the user at each stage of development can select the simulation using the block macro model, its circuitry solution, or use the experimental solution data (Fig. 3.).

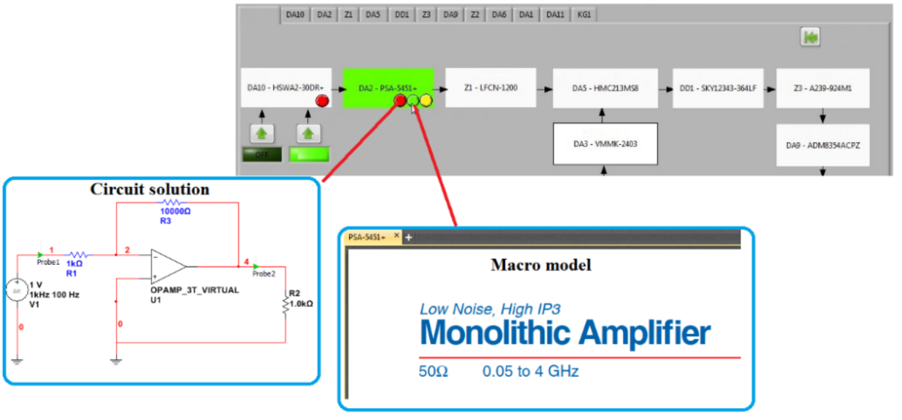


Fig. 3. Equipment design capabilities at various levels.

The simulation results can be displayed in the usual representation for the developer of electronic equipment- in the form of oscillograms, as well as in the form of the results of spectral analysis, an example of a solution for two options is shown in Fig. 4 and 5, respectively. Such a presentation of the results, as a rule, facilitates an understanding of the physical processes occurring both in the radio engineering system as a whole and in its specific functional units, and contributes to the development of correct solutions to the problem.

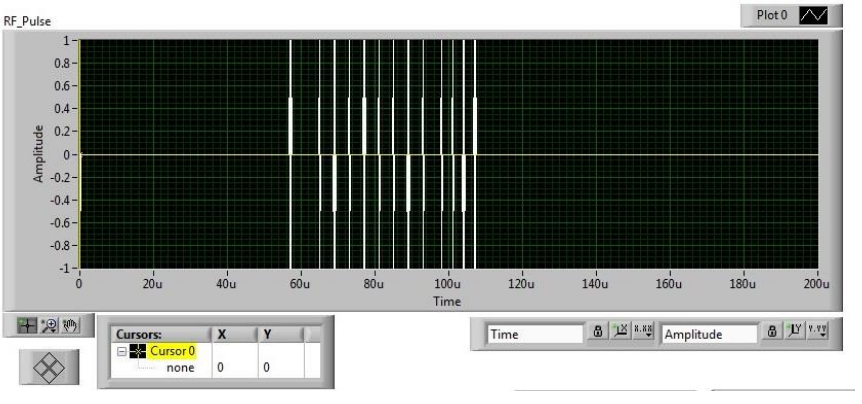


Fig. 4. The result of the simulation in the form of an oscillogram.

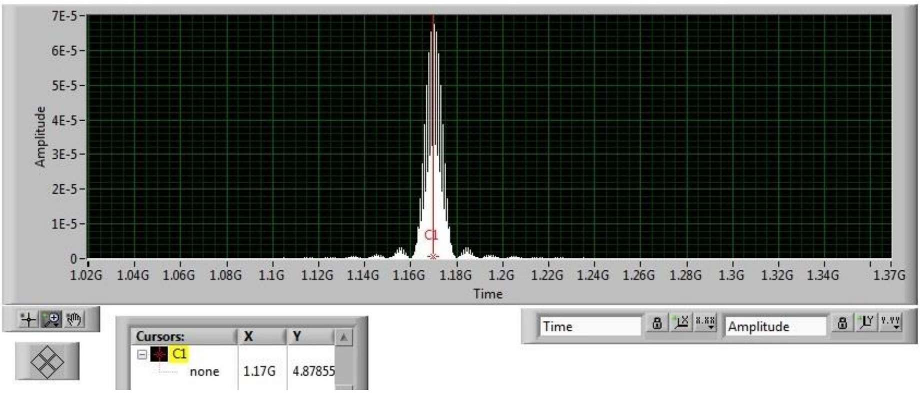


Fig. 5. The result of the simulation in the form of spectral analysis.

The receiving path in the SEM NS is built on the principle of a superheterodyne receiver. The advantages of this type of construction schemes are the ability to obtain high-frequency amplification and selectivity at a fixed intermediate frequency. The latter is selected in the range for which amplifying devices are available and it is possible to provide the necessary quality factor of circuits, greater stability of high-frequency amplification, part of the gain is received at the frequency of the signal, and part is at the intermediate frequency. In receivers of this type, the main amplification to the detector is carried out by stages of an intermediate frequency amplifier (IFA) tuned to a fixed frequency, which is formed in the mixer as a result of the interaction of the input signal and the local oscillator signal. The dynamic range of the signal is quite large, and the determination of spatial coordinates requires a stable signal arriving at the processing system. In this regard, the automatic gain control (AGC) system is used as part of the SEM receive path. The AGC system includes an attenuator and a comparison device, which are controlled using a programmable logic element. Stabilization of the voltage level is achieved due to the operation of the AGC system based on the binary weighing algorithm. The front panel and a fragment of the AGC routine for SEM are shown in Fig. 6 and 7, respectively.

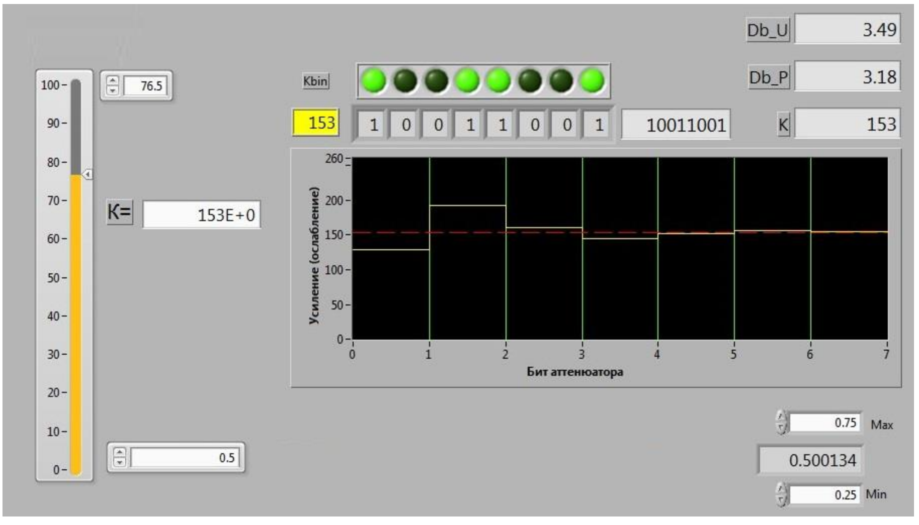


Fig. 6. The front panel of the AGC system.

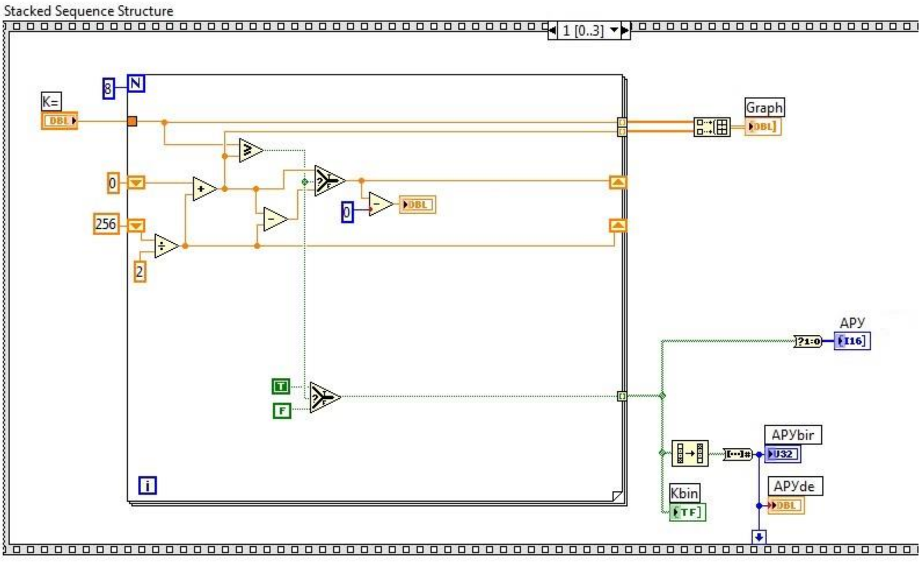


Fig. 7. Fragment of a simulation model of the AGC system.

It is known that the functioning of any electronic equipment always occurs when exposed to various external factors. In this regard, for developers of electronic equipment of any complexity, the actual task is to determine the effect of various external noise interference on the accuracy of signal reception and processing.

Such an approach to the implementation of hardware and software systems will allow you to create a simulation model for analyzing the interference situation by introducing noise signals with various parameters into the model, as well as for analyzing the accuracy of determining the coordinates under the influence of these interference. The parameters of the interference signal are determined by the user depending on the requirements for the interference environment.

The front panel view to demonstrate the possibility of introducing a noise component into the signal supplied to the input of the comparator of the system for determining the coordinates of further calculation is shown in Fig. 8.

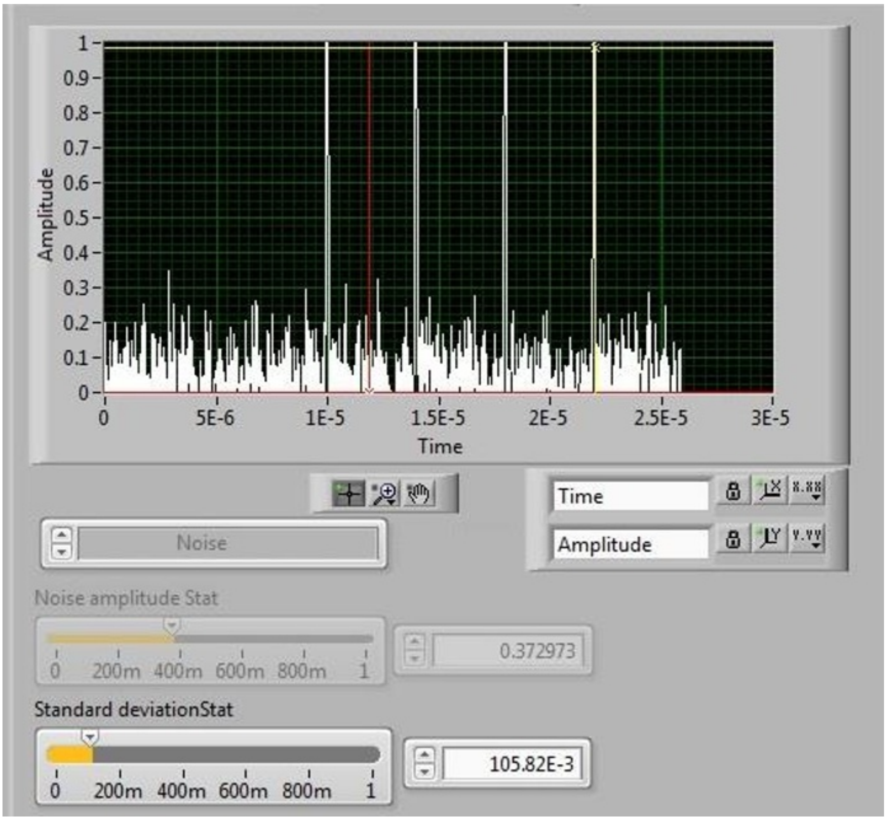


Fig. 8. Simulation front panel to demonstrate the ability to incorporate a noise component into a useful signal.

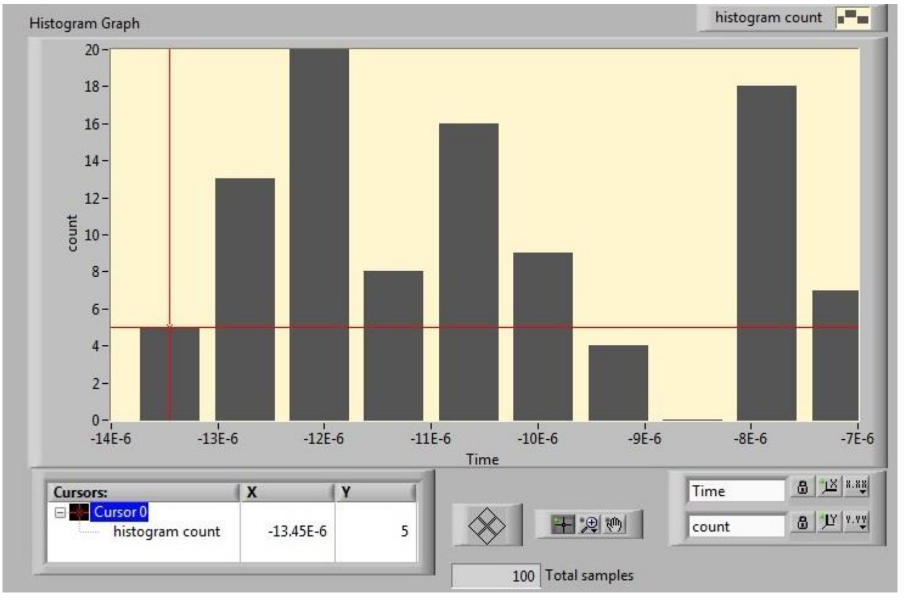


Fig. 9. The results of the simulation model in the analysis of the accuracy of determining the coordinates.

3 Conclusion

Due to the capabilities of constructing such software and hardware systems in the form of simulation models, the user can analyze the accuracy of determining coordinates using the construction of histograms of measurement results, as well as post-process the results in mathematical programs Mathcad, MATLAB and others, using the data obtained from the analysis of work simulation model. The authors have previously shown the creation of a simulation model using the MATLAB / Simulink environment.

Today, at the time of the dynamically developing world of computer technology, it is necessary to introduce such an approach as simulation, since the development of complex systems in general, and individual functional units of the system in particular, is becoming evident.

Obviously, this approach to the creation of software and hardware systems in the form of such simulation models is promising not only in the educational process at universities, but also in the application at various engineering courses.

Computer modeling is necessary both for the modernization of engineering courses, since the operation of the system as a whole and its specific units is clear and easy to understand in the training of engineers, and for the advanced training of engineers who already have experience working with both REA and measuring equipment.

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