3. **Молчадский, И. С.** Пожар в помещении / И. С. Молчадский. – М.: ВНИИПО, 2005. – 456 с.

4. **Experimental** and Theoretical Model of Flashover / P. G. Holbom [et al.] // Fire Safety Journal. – 1993. – Vol. 21, No 3. – P. 257–266.

5. **Graham, T. L.** On the Theory of Flashover Development / T. L. Graham, G. M. Makhviladze, J. P. Roberts // Fire Safety Journal. – 1995. – Vol. 25, No 3. – P. 229–259.

6. **Poulsen, A.** Experimental Study on the Burning Behavior of Pool Fires in Rooms with Different Wall Linings / A. Poulsen, G. Jomaas // Fire Technology. – 2012. – Vol. 48, No 2. – P. 419–439.

7. **Novozhilov, V.** Non-Linear Dynamical Model of Compartment Fire Flashover / V. Novozhilov // Journal of Engineering Mathematics. – 2010. – Vol. 67, No 4. – P. 387–400.

8. **Fire** Dynamics Simulator (Version 5) Technical Reference Guide Volume 1: Mathematical Model, NIST Special Publication 1018-5 / K. McGrattan [et al.]. – Gaithersburg: MA, 2008. – 92 p.

9. **Forney, G.** User's Guide for Smokeview Version 5: A Tool for Vizualizing Fire Dynamics Simulation Data, NIST Special Publication 1017-1 / G. Forney. – Washington: U.S. Government Printing Office, 2008. – 142 p.

10. **Невдах, В. В.** Моделирование начального этапа стационарного пламенного пожара в закрытом помещении / В. В. Невдах, А. А. Антошин, И. Е. Зуйков // Наука и техника. – 2014. – № 3. – С. 28–35.

R E F E R E N C E S

1. **Drysdale, D.** (2011) *An Introduction for Fire Dynamics*. Third Edition. Chichester, Willey. 551 p. Doi: 10.1002/9781119975465.refs.

2. **Koshmarov, Yu. L.** (2000) *Danger Factor Forecasting of Fire in the Premises*. Moscow, State Fire Academy of EMERCOM of Russia. 118 p. (in Russian).

3. **Molchadsky, I. S.** (2005) *Fire in Premises.* Moscow, All-Russian Scientific-Research Institute for Fire Protection [VNIIPO]. 456 p. (in Russian).

4. **Holbom, P. G.,** Bishop, S. R., Drysdale, D. D., & Beard, A. N. (1993) Experimental and Theoretical Model of Flashover. *Fire Safety Journal,* 21 (3), 257–266. Doi: 10.1016/0379-7112(93)90030-T.

5. **Graham, T. L.,** Makhviladze, G. M., & Roberts, J. P. (1995) On the Theory of Flashover Development. *Fire Safety Journal,* 25 (3), 229–259. Doi: 10.1016/0379-7112(95)00049-6.

6**. Poulsen, A.,** & Jomaas, G. (2012) Experimental Study on the Burning Behavior of Pool Fires in Rooms with Different Wall Linings. *Fire Technology*, 48 (2), 419–439. Doi: 10.1007/s10694-11-0230-0.

7. **Novozhilov, V.** (2010) Non-Linear Dynamical Model of Compartment Fire Flashover. *Journal of Engineering Mathematics,* 67 (4), 387–400. Doi: 10.1007/s10665-009-9333-8.

8. **McGrattan, K.,** Hostikka, S., Floyd, J., Baum, H., & Rehm, R. (2008) *Fire Dynamics Simulator (Version 5) Technical Reference Guide Volume 1: Mathematical Model*. NIST Special Publication 1018-5, National Institute of Standards and Technology, Gaithersburg, MA. 92 p.

9. **Forney, G.** (2008) *User's Guide for Smokeview Version 5: A Tool for Vizualizing Fire Dynamics Simulation Data.* NIST Special Publication 1017-1. Washington: U.S. Government Printing Office. 142 p.

10. **Nevdakh, V. V.,** Antoshin, A. A., & Zuikov, I. E. (2014) Initial Stage Simulation of Stationary Flaming Fire in the Closed Premises. *Nauka i Tekhnika* [Science & Technique], 3, 28–35 (in Russian).

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INTELLECTUAL MECHATRONIC SYSTEMS WITH REMOTE COMPONENT INTERACTION: STRUCTURE AND FUNCTIONS

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Basic requirements to sensor and controlling tracts of mechatronic systems with the remote organization of object control processes have been considered in the paper. A rational approach presupposes designing of the mentioned systems as multichannel technical complexes intended for parallel or quasi-parallel force-moment control of outlet mechanical links (motion modules) by multiple coordinates of the required phase space. It has been shown that the use of digitizing principles and distributed data procession in mechatronic systems makes it possible to pass to the unified structure and typical set of software and hardware functions of the aforesaid tracts.

The paper gives consideration to a structural and functional scheme of the mechatronic system which contains an intellectual sensor device, a controlling center and an intellectual executive mechanism. The tasks that are linked with organization of preliminary information procession and construction of the systematic interface for transfer of telemetric transactions between controlled objects and the control center have been specified in the paper. Solution of a functionally full set of logically completed tasks is imposed to software and hardware tracts of the mechatronic system which is based on the abovementioned principles.

The paper presents preliminary distribution of functions according to the system resources that is between an intellectual sensor unit, a control center and an intellectual executive mechanism. One of the most important features is an informational compatibility of the system components which is achieved owing to the use of unified transactions. The noise immune data coding expands useful informational transaction volume to some actual volume. It has been shown that construction of tract transfer and transaction reception in the intellectual mechatronic system on the basis of radio channels is considered as the most complicated technical solution.

Keywords: intellectual mechatronic systems, components, structure, function.

Fig. 1. Tab. 1. Ref.: 9 titles.

ИНТЕЛЛЕКТУАЛЬНЫЕ МЕХАТРОННЫЕ СИСТЕМЫ С ДИСТАНЦИОННЫМ ВЗАИМОДЕЙСТВИЕМ КОМПОНЕНТОВ: СТРУКТУРА И ФУНКЦИИ

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Проанализированы базовые требования, предъявляемые к сенсорным и управляющим трактам мехатронных систем с дистанционной организацией процессов контроля и управления объектами. Рациональным подходом является проектирование указанных систем как многоканальных технических комплексов, рассчитанных на параллельное или квазипараллельное силомоментное управление выходными механическими звеньями (модулями движения) по множеству координат требуемого фазового пространства. Показано, что применение в мехатронных системах принципов цифровизации и распределенной обработки данных позволяет перейти к унифицированной структуре и типовому набору функций аппаратных и программных средств указанных трактов.

Рассмотрена структурно-функциональная схема мехатронной системы, содержащей интеллектуальное сенсорное устройство, центр управления и интеллектуальный исполнительный механизм. Специфицированы задачи, связанные с организацией предварительной обработки информации и построением системного интерфейса передачи телеметрических транзакций между контролируемыми объектами и центром управления. На аппаратные и программные средства трактов мехатронной системы, построенной на основе указанных принципов, возлагается решение функционально полного набора завершенных в логическом отношении задач.

Представлено предварительное распределение функций по ресурсам системы – между интеллектуальным сенсорным устройством, центром управления и интеллектуальным исполнительным механизмом. Один из важнейших показателей – информационная совместимость составных частей системы – достигается за счет применения унифицированных транзакций. Помехоустойчивое кодирование данных расширяет полезный информационный объем транзакции до некоторого фактического объема. Показано, что наиболее сложным техническим решением является построение в интеллектуальной мехатронной системе трактов передачи и приема транзакций на основе радиоканалов.

Ключевые слова: интеллектуальные мехатронные системы, компоненты, структура, функция.

Ил. 1. Табл. 1. Библиогр.: 9 назв.

Combination of radio electronic equipment, algorithms of digital procession of information and software makes it possible to create multifunctional mechatronic systems having a high level of combination of fulfilled functions. A rational approach includes design of the said systems as multichannel technical complexes intended for parallel or quasi-parallel force-moment control of outlet mechanical links (motion modules) by multiple coordinates of the required phase space [1, 2]. Within the frameworks of this approach basic requirements have been analyzed to sensor and controlling tracts of mechatronic systems with remote organization of transactions. A structural and functional scheme of the mechatronic system has been considered, which contains an intellectual sensor device, a controlling center and an intellectual executive mechanism. The full functional set of tasks has been provided to be resolved with the aid of hardware and software of the intellectual mechatronic system.

Structural unification of intellectual mechatronic systems having the remote organization of transactions. At preliminary stages of designning the mechatronic systems a basic set of certain structural and functional requirements is formed. In accordance with technical standard and legal acts in the field of technical regulation these requirements specify the following aspects of systems construction:

• composition and types of control objects;

• quantity of control coordinates in the phase space and the required laws (types of trajectories) of motion modules travel;

• speed and precision features of processes of changing the location of working bodies;

• allowed parameters of control persistence;

• remoteness of objects from the controlling center, types, supposed quantity and specifications of channels of exchange between telemetry and telematics transactions;

• radio interface for transmission of transactions between controlled objects and the controlling center for provision of their remote interaction and required probability and time rates;

• parameters of the expected mechanical, climatic, electromagnetic and other destabilizing impacts of the functioning environment onto components of systems and methods of provision of functional control of components;

• necessity of system protection from non-sanctioned access to its resources, from falsifications and information obtrusion.

In practice, a wide spectrum of heterogeneous requirements can rather hardly be satisfied in case of a "concatenated" approach to design of systems, when "appropriate" components are selected and they are mutually linked at the place of application in accordance with the preset requirements. Presently, this approach prevails during construction of complex mechatronic systems. However, the seeming economy and natural character of the synthesis process of a specific system mostly lead to conservatism of relations in its structure, and this is accompanied with essential technical complications along with possible modification of the system itself and its individual components. It should also be pointed out that in this case when the mechatronic system is created, extra problems are caused by its functioning reorganization.

An alternative approach includes design of mechatronic systems as the single whole on the principles of digitizing and distributed data procession. These principles have been known for a rather long period, but they have acquired a new technical sounding due to development of relatively cheap highly productive microprocessors in mass production and elaboration of practical applications of the theory of digital procession of signals [3–5]. Presently, objective technical, algorithmic and economical conditions exist for transition to the unified structure and a typical set of hardware and software functions of mechatronic systems. A possible structure option of the intellectual mechatronic system of the aforesaid type is shown in fig. 1.

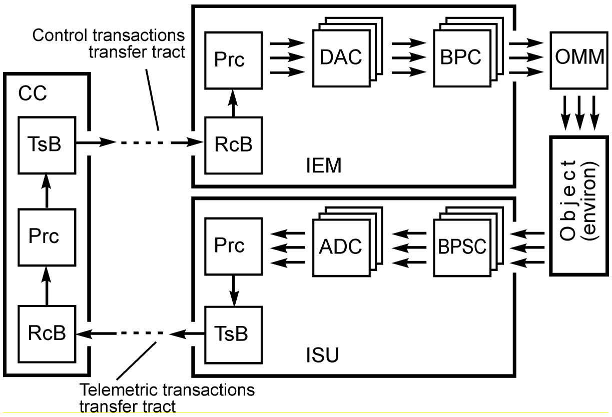

Fig. 1. Structural and functional scheme of the intellectual mechatronic system with the remote organization of transactions

Control processes in the structure under consideration are directed for provision of the required laws of travel of the output motion module (OMM). The control center (CC) includes a processor (Prc) which is intended for consolidated procession and accumulation of the systematic information, solution of preset functional tasks and elaboration of controlling impacts, fulfillment of control procedures for components, as well as, if necessary, for keeping and archiving the functioning protocols. Besides, a transmitting block (TsB) is included to the control center for output of control transactions and a reception block (RcB) for input of telemetric transactions. Additionally, the control center may include an operator's console and a visualization data block.

Remote multiparameter control of the motion module is implemented with the aid of control transactions and the intellectual executive mechanism (IEM). The executive mechanism provides transformation of transactions with digital control vectors to analog, discrete and impulse signals of the required axis motion or to changes of the motion module state in the phase space. The executive mechanism includes a reception block, a processor, digital-to-analog, digital-discrete, digital-impulse converters (DAC, DDC, DIC, respectively) and a block of power converters (BPC). In this case the processor provides digital implementation of convolutions of the control vector digital signals and impulse specifications corresponding to the required transfer functions which determine the motion module control dynamics. So, purposive movement of the aforesaid module is provided in the system along with control of its position and state with the aid of the feedback tract.

Remote multiparameter control of the current position and the state of the output motion module state in the feedback tract is carried out with the aid of telemetric transactions and an intellectual sensor unit (ISU). This unit implements processes of preliminary digital procession of signals, which define the current position and the state of the motion module, as well as their conversion to the control vector which is accompanied with a time sign. A block of primary sensor converters (sensors) (BPSC) is introduced to the sensor unit, as well as analog-to-digital, discrete-digital and impulse-digital converters (ADC, DDC, IDC, respectively), a processor and a transmitting block.

With the aim of arranging the remote informational interaction wired channels, fiber-optic and radio channels are used, and being so, the best probabilistic and time specifications are obtainned when two separate simplex channels are used. The use of one simplex wired or radio channel in the semi-duplex mode is allowed for control of inertial objects (based on application of channel separation in time and an access method with the carrying frequency control [5, 6]).

Transfer of main processes of signals procession and other information to software and their distribution by processors of the mechatronic system makes it possible to build a unified highly stable structure which acquires the properties of adaptation to changes of the output motion module and functioning modes, as well as possible modifications of types and functions of system components. Standardization of digital interconnection interfaces which at present is rather strictly observed by developers and manufacturers of radio-electronic equipment provides extra conditions for flexible functional system conversions along with preservation of its general structure. Such a standardization is achieved by means of selection of the required composition of the aforesaid converters, a block of sensitive components and respective modifications of “soft components” – the programs for digital procession of signals and data in processors.

Distribution of a set of functions between components of the intellectual mechatronic system. Solution of the functionally full set of logi cally completed tasks may be imposed on hardware and software of the mechatronic system tracts. The following plan of their preliminary distribution by resources of the system seems to be rational.

Intellectual sensor unit:

- digitization of analog, discrete and impulse signals formed by sensitive components by taking into account the a priori data on parameters of frequency spectra of signals;
- provision of linearization, positioning, calibration and metrological expertise of digital measuring converters;
- primary digital procession of signals, including digital filtration and required logical conversions;
- measuring information blocking along with its “binding” to numbers of measuring channels in a tract, formation of the controlling vector and its representation in the telemetric transaction format;
- formation of a transaction imitation protecting code with the use of a confidential parameter for protection of the system from forgeries and information intrusion [7];
- noise-immune transaction coding depending on a priori data about statistical properties of radio channels (the use of cyclic codes, Golay or Reed-Solomon codes and others [8]);
- interleaving of transaction codes for protection from possible blocks (packs) of bit errors [8];
- transmission of telemetric transactions to the control center.

Control center:

- reception of telemetric transactions from the intellectual sensor unit to the control center and reverse interleaving of transaction codes;
- withdrawal of the noise-immune code and formal control of transaction correctness;
- formation of the transaction imitation protection code with the use of a confidential parameter and check of authenticity;
- sensor information unpacking along with allocation of numbers of channels, results of parameters control and time marks in the atomic view;
- notional information procession, its accumulation, if necessary – data visualization, generation of controlling impacts on the output motion module by phase space coordinates;

• controlling information binding along with its "binding" to control tract channels numbers, formation of the control vector and its representation in the telematics transaction format;

• formation of the transaction imitation protection code with the use of a confidential parameter for motion module protection from forgeries and information intrusion;

• noise-immune transaction coding and interleaving of transaction codes;

• transfer of transactions to the intellectual executive mechanism.

Intellectual executive mechanism:

• reception of telemetric transactions from the control center to the executive mechanism and reverse interleaving of transaction codes;

• withdrawal of the noise-immune code and formal control of transaction correctness;

• formation of the transaction imitation protection code with the use of a confidential parameter and check of authenticity;

• controlling information unpacking along with allocation of numbers of channels, controlling parameters and time marks in the atomic view;

• controlling information procession and its distribution by channels preset in a transaction;

• physical reproduction of analog, discrete and impulse signals and impact on the required accessories of the output motion module with the aid of corresponding power converters.

Tasks of the intellectual mechatronic system may be expanded due to introduction of software implemented adjustment functions and changes of system parameters, testing and periodic control of equipment. Informational compatibility of system components is achieved owing to application of unified transactions. A possible logical structure of telemetric and telematic transactions is shown in tabl. 1.

Table 1

Logical structure of telemetric and telematic transactions

Systematic identifier of telemetric (telematic) tract	Transaction type	Current transaction number
Channel number	Parameter type	Binary time code
Binary parameter code		
Channel number	Parameter type	Binary time code
Binary parameter code		
• • •	• • •	• • •
Imitation protecting code		

When 16-digit processors are used, identifying information representation in the service heading of the transaction may in principle be limited with three logical fields, and it may have the total length of 32 bits. In case of introduction of extra attributes, including the address fields for operation in the network mode, the heading may be expanded up to 64 bits. Usually, 32 bits are enough for location of the transaction imitating protection code. Representation of information about one parameter in a transaction can be provided with the aid of three logical fields having the total length of 48 bits. When the total useful informational volume of information is equal to n_{inf} = 1040 bits, the mechatronic system is capable of controlling by 20 coordinates of the phase space, what complies with the contemporary requirements [1, 2].

The noise-immune coding expands the useful informational volume of n_{inf} transaction to some actual volume n. Block codes for correction of errors are usually shown as triplets (n, k, d), wherein n is the actual volume of the code combination of a single block; k is the number of informational bits in the code combination of a block; d is the minimum Hamming distance between various cody combinations. The repetition factor of errors t to be corrected by means of a code shall be determined by the ratio $(d – 1)/2$. In case of the speed of errors P_{err} in channels of transactions transmission and reception tracts selection of the noise-immune coding is the most important task of the systematic interface design.

In case of the symmetric channel model the following criterion ratio must be provided from each transaction block:

$$(1 - P_{err})^n + C_n P_{err}(1 - P_{err})^{n-1} + C_n^2 P_{err}^2 (1 - P_{err})^{n-2} + \\ + \ldots + C_n^t P_{err}^t (1 - P_{err})^{n-t} > (P_{auth})^{1/Rbl},$$

wherein P_{auth} is the required authenticity of transfer of telemetric and telematic transactions (usually at the level of 0.990–0.999); $R_{bl} = S_{up}(n_{inf}/k)$ – quantity of informational blocks with the account of noise-immune coding a s a part of transactions. The actual volume of the transaction is determined by the ratio $n_{act} = nR_{bl}$, and the actual volume of the transaction informational block after its noise-immune coding is set by the product $n = kq_{red}$, wherein q_{red} is the factor of noise-immune code redundancy.

As a matter of fact, rational solution of the nonlinear multi-parameter task should be found, and an option of the noise-immune coding should be selected, which will, if possible, maximize the volume *k* in case of observance of the criterion correlation. For example, the (24; 12; 7)-expanded Golay code provides detection and correction by 3 errors in an informational block consisting of 12 bits with the redundancy factor q_{red} = 2. However, in case of this code redundancy factor for noise-immune transfer of 1040 transaction bits with authenticity 0.99 the actual transfer of 87 blocks will be required with the total volume of 2080 bits with authenticity of transfer of every block not below 0.9999. Construction of a more preferable cyclic (63; 45; 7)-code is possible which also provides detection and correction up to 3 errors, but the informational block of such a code consists of 45 bits with the redundancy factor q_{red} = = 1.4. In this case for the noise-immune transfer of 1040 transaction bits with authenticity 0.99 the actual transfer of 24 blocks will be required with the total volume of 1512 bits with authentic transfer of every block not below 0.9996.

Construction of transactions transfer and reception tracts in the mechatronic system on the basis of radio channels is the most complicated technical solution. Radio channels have rather high speeds of errors with the values P_{err} = 0.0100–0.0005, whereas wired and fiber-optic channels have speeds of errors P_{err} = 0.000100–0.000001 and even lower values. Radio channels of the ultra short wave range in the permitted frequency bands (146–174 and 380–470 MHz) provide the nominal speed of digital information with the use of the quadrature QPSK-modulation on the level of 9600 bits/s [6, 9, 10]. The estimated time of transfer of transactions constituting 0.2166 and 0.1575 s, respectively, for the considered coding options essentially determines signal delay and system lag.

Practical construction of mechatronic system with the unified structure and distributed information procession is mostly related to establishment of software for the control center processors, the intellectual sensor module on the basis of the methods and regularities of the automatic control. Design of intellectual mechatronic systems also requires rational construction of the systematic interface which essentially influences probabilistic and time properties of the established units.

CONCLUSIONS

When intellectual mechatronic systems are formed, a basic set of certain structural and functional requirements is formed, which specify main aspects of construction of these systems. Their designing as the single whole on the principles of digitizing and the distributed data procession is a rather productive approach to establishment of intellectual mechatronic systems. Solution of a functionally full set of logically completed tasks is imposed to software and hardware tracts of the mechatronic system based on the aforesaid principles. This work shows preliminary distribution of functions by the system resources – between the intellectual sensor unit, the control center and the intellectual executive mechanism. One of the most important features includes informational compatibility of system components which is achieve owing to the use of unified transactions. The noise immune data coding expands the useful informational transaction volume to some actual volume. It has been shown that construction of transactions transfer and reception tracts in the mechatronic system on the basis of radio channels is the most complicated technical solution.

REFERENCES

1. **Fedotov, A. V.** (2007) *Use of Automatic Control Theory Methods While Developing Mechatronic Systems*. Omsk: Publishing House of Omsk State Technical University. 84 p. (in Russian).

2. **Voronov, A. A.** (1986) *Automatic Control Theory*. Parts 1, 2. Moscow, Vysshaya Shkola. (in Russian).

3. **Speransky, V. S.** (2008) *Signal Micro-Processors and Their Application in Telecommunication Systems and Electronics*. Moscow, Hotline – Telekom. 170 p. (in Russian).

4. **Brodin, V. B.,** & Shagourin, M. I. (1999) *Micro-Controllers. Architecture, Programming, Interface. Reference Book*. Moscow, EKOM Publishing House. 401 p. (in Russian).

5. **Smith, S. W.** (2002) *Digital Signal Processing. A Practical Guide for Engineers and Scientists*. Kalifornia, San-Diego, Kalifornia Technical Publishing. 643 p. (Russ. ed.: Smith, S. (2008) *Tsifrovaia Obrabotka Signalov. Prakticheskoe Rukovodstvo dlia Inzhenerov i Nauchnykh Rabotnikov*. Moscow, Publishing House “DodEka-XXI”. 720 p.)

6. **Feher, K.** (1995) *Wireless Digital Communications. Modulation and Spread Spectrum Applications*. NY, Prentice Hall PTR. 544 p. (Russ. ed.: Feher, K. (2000) *Besprovodnaia Tsifrovaia Sviaz'. Metody Moduliatsii i Rasshireniia Spectra*. Moscow, Radio i Svyaz. 520 p.)

7. **Kharin, Yu. S.,** Bernik, V. I., Matveev, G. V., & Agievich, S. V. (2003) *Mathematical and Computer Fundamentals of Cryptology*. Minsk, Novoe Znanie. 381 p. (in Russian).

8. **Clark, G. C.** & Cain, J. B. (1981**)** *Error-Correction Coding for Figital Communications*. Springer. 432 p. (Russ. ed.: Clark, G. C. & Cain, J. B. (1987) *Kodirovanie s Ispravleniem Oshibok v Sistemakh Tsifrovoi Sviazi*. Moscow, Radio i Svyaz. 391 p.)

9. **Moscow** State University, Faculty of Physics, Department of “Radio Physics Microwave”. (2008) *Selection of Optimum Method for Signal Modulation in Modern Digital Communication Systems*. Moscow, Publishing House of Moscow State University [MSU]. 52 p. (in Russian).

10. **Stollings, W.** (2002) *Wireless Communications and Networking*. New Jersey, Pearson Education, Inc. 547 p. (Russ. ed.: Stallings, W. (2003) *Besprovodnye Linii Sviazi i Seti*. Moscow; Saint-Petersburg, Williams Publishing House. 638 p.)

Л И Т Е Р А Т У Р А

1. **Федотов, А. В.** Использование методов теории автоматического управления при разработке мехатронных систем / А. В. Федотов. – Омск: Изд-во ОмГТУ, 2007. – 84 с.

2. **Теория** автоматического управления: учеб. для вузов: в 2 ч. / под ред. А. А. Воронова. – М.: Высш. шк., 1986. – Ч. 2.

3. **Сперанский, В. С.** Сигнальные микропроцессоры и их применение в системах телекоммуникаций и электроники / В. С. Сперанский. – М.: Горячая линия – Телеком, 2008. – 170 с.

4. **Бродин, В. Б.** Микроконтроллеры. Архитектура, программирование, интерфейс: справ. / В. Б. Бродин, М. И. Шагурин. – М.: ЭКОМ, 1999. – 401 с.

5. **Смит, С.** Цифровая обработка сигналов: практ. руководство для инж. и науч. работников / С. Смит; пер. А. Ю. Линович, С. В. Витязев, И. С. Гусинский. – М.: ДодЭка-XXI, 2008. – 720 с.

6. **Феер, К.** Беспроводная цифровая связь. Методы модуляции и расширения спектра / К. Феер; пер. с англ. В. И. Журавлев. – М.: Радио и связь, 2000. – 520 .

7. **Математические** и компьютерные основы криптологии / Ю. С. Харин. [и др.]. – Минск: Новое знание, 2003. – 381 с.

8. **Кларк, Дж. К.** Кодирование с исправлением ошибок в системах цифровой связи / Дж. К. Кларк, Дж. Б. Кейн; пер. с англ. С. И. Гельфанда. – М.: Радио и связь, 1987. – 391 с.

9. **Выбор** оптимального метода модуляции сигнала в современных цифровых системах связи: спецпрактикум / Московский государственный университет. – М.: Изд-во МГУ, 2008. – 52 с.

10. **Столлингс, В.** Беспроводные линии связи и сети / В. Столлингс. – М.; СПб.: Вильямс, 2003. – 638 с.

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СОВЕРШЕНСТВОВАНИЕ ЭКСПЕРТНОГО АНАЛИЗА ДОРОЖНО-ТРАНСПОРТНЫХ ПРОИСШЕСТВИЙ С ПОМОЩЬЮ КОМПЬЮТЕРНЫХ ПРОГРАММ МОДЕЛИРОВАНИЯ

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Существующие методики проведения автотехнической экспертизы предполагают выбор некоторых параметров на основе интуиции и опыта эксперта. Также при определении замедления не учитываются марка транспортного средства и степень его загрузки, дорожные условия. В процессе анализа установлено, что применение специального программного обеспечения позволяет значительно повысить эффективность выполняемых работ по решению поставленных задач, ускоряет процесс расчетов, в качественном плане уменьшает вероятность ошибок арифметического характера и дает возможность визуализации результатов произведенного исследования. Установлены возможности использования различных моделей для динамического моделирования движения и столкновений автомобилей (в виде трехмерной модели). При этом учитываются особенности технического состояния автомобилей и загрузки, состояние поверхности дорожного покрытия, а также динамического отображения реконструированного механизма ДТП в аксонометрической проекции, создание видеороликов с расположением камеры в произвольной точке пространства: на дороге, обочине, возвышении, движущемся транспортном средстве, водительском месте в транспортном средстве.

Выполнены анализ возможностей программ моделирования дорожно-транспортных происшествий, статистический анализ значимости отличий между результатами моделирования при помощи различных программ. Приведены исходные данные и результаты расчета скорости движения транспортного средства по длине следа торможения, полученные с помощью программ экспресс-анализа ДТП (классический подход) и PC-Crash (учитываются дополнительные влияющие факторы). В ходе исследования результатов моделирования применяемого программного обеспечения выявлен ряд недостатков, подлежащих доработке в анализируемых программных продуктах. На основании проведенного анализа использования программ моделирования ДТП предложено к практической работе привлекать ответственные и контролирующие органы (ГАИ, экспертные учреждения, страховые компании) для повышения объективности результатов заключений.

Ключевые слова: дорожно-транспортные происшествия, экспертный анализ, компьютерная программа моделирования.

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