CONTENTS AND ABSTRACTS

RADIO ENGINEERING AND COMMUNICATION SYSTEMS

E. P. VASILIEV, D. H. NGUYEN. NUMERICAL ANALYSIS OF DESIGN OPTIONS OF MINIATURE RADAR RESONANT ELEMENTS

The designs of six compact resonant elements for communication systems of moving objects in the centimeter range are considered. A study of design options for resonant elements using electrodynamics finite element method is carried out. The aim of the work is to study various design solutions of resonant elements for the purpose of a comparative analysis of main quality indicators (gain, band-width, standing wave ratio, side lobes level and dimensions). An algorithm to integrate modern computing tools for modeling patch antennas is proposed and tested. The correctness of the simulation results is confirmed by a comparative analysis of the experimental results with the data of computer calculations obtained using finite element method in X-band.

A. V. BOGOSLOVSKY. ANALYTICAL METHODS TO SYNTHESIZE ANTENNA ARRAYS OF MOBILE RADIO ENGINEERING COMPLEXES

The principles of antenna arrays synthesis intended to be used as part of mobile radio engineering complexes are presented. Synthesis is performed at a given topology of the receiving-emitting structure with established relationships between the parameters of its structure and the efficiency indicators of signal radiation (reception) set on the basis of the requirements for radio engineering complexes. Its essence lies in the rational choice of parameters for the implementation of compromise technical solutions to achieve the required characteristics under the constraints established from the design and typical conditions of complexes application. The development of analytical methods for the synthesis of annular lattices has been carried out. When synthesizing radiation patterns of receiving-emitting structures with the levels controlled in specified directions and in order to reduce the amplification losses of the emitted (received) signals, the methods based on minimizing diagram functionals are shown to be most expedient. Efficient procedures to find extreme values of functionals are implemented using electrodynamic modeling packages (programs) such as CST MWS – Computer Simulation Technology Microwave Studio and Altair FEKO – FEldbe-rechnung bei Korpern mit beliebiger Oberflache.

The aim of the work is to substantiate the principles and to develop methods for the synthesis of antenna arrays in the interests of forming rational appearance of radio engineering complexes.

V. V. ZOLOTAREV, G. V. OVECHKIN. QUICK LOOK CODES MAJORITY DECODING FOR ERROR CORRECTION IN COMMUNICATION CHANNELS

Key words: optimization coding theory, quick look codes, Viterbi algorithm, multi-threshold decoding algorithm, main theorem of multithreshold decoding, optimal decoder, codes with multiple rates, modeling.

The problem of error correction in data transmission over noisy channels is considered, the effective solution of which is based on the use of error-correcting codes and decoding methods. The aim of the work is to obtain the characteristics of quick look non-systematic convolutional and block codes and analyze their capabilities when used in optimal Viterbi algorithms of various types, as well as in new majority-type schemes, in which they are characterized by very high efficiency. The capabilities of these algorithms in binary-symmetric channels and the channels with additive white Gaussian noise are described. Their parameters in block coding systems are discussed. The possibilities of this new direction in applied coding theory, also based on the best results and achievements of Optimization Coding Theory, are indicated.

K. I. SUKACHEV, D. P. GRIGORIEV, D. A. SHESTAKOV, A. A. ARTYUSHIN, A. V. RODINA. DEVELOPMENT OF A RING HALF-DUPLEX NETWORK FOR DATA EXCHANGE BETWEEN DEVICES IN SCIENTIFIC SPACE EQUIPMENT

Key words: FPGA, CPLD, Microcontroller, Half-duplex Network, Manchester Code, SAINT, infinite loop, FMU Core, Spacecraft, Scientific Equipment.

The architecture of the ring (bubble) half-duplex network «IL net» is considered, namely: low network level (circuit implementation of communication line, SIINT data exchange puncture, ring bus controller) and high network level (ring connection of devices). The interface contains a communication line in the form of twisted pair, with transformer isolation between the devices. A feature of the interface is the Manchester signal encoding in terms of increasing noise immunity, adaptive adjustment of data transfer rate, which removes the need for the developer to be tied to single speed for all devices, whether it is a master or a slave. The interface also has bubble bus support, which allows for long-term operability of the communication channel when one of the communication lines breaks. All packets contain a verification frame with a checksum, and data frame is encrypted with a special bit sequence to protect against unauthorized data reading between devices.

E. I. GURIN, S. V. TUMASOV. METHOD OF INFORMATION SYNCHRONIZATION AND PROCESSING IN COMPUTING NETWORKS ON SPREAD SPECTRUM SIGNALS

Key words: spread spectrum signals, computer networks, synchronization, microcontrollers, protocols, pseudo-noise sequences, information transmit, wireless networks, MSP430.

Well-known works haven't thoroughly considered the issue of computer network nodes synchronization on spread spectrum signals of the «Internet of things» sphere in difficult terrain conditions and in the presence of interference in the channel. In this regard, the development of a method for synchronization and information processing and its implementation for wireless computer networks based on spread spectrum signals is an

urgent research task. The aim of the work is to develop a method for synchronization and information processing, its implementation for wireless computer networks with low power consumption using spread spectrum signals in difficult natural conditions of wooded area. The method has been developed for synchronization and information processing for wireless computer networks based on spread spectrum signals for wooded areas and under interference conditions. The method presented is implemented for a computer network with low power consumption in the «Internet of Things» sphere on MSP430 microcontrollers and transceiver modules. The method of synchronization and information processing given here makes it possible to ensure the synchronization of transmitter and receiver of wireless network, most fully takes into account difficult natural conditions of wooded area and interference effects.

M. S. LUSHNINA, E. S. SHTRUNOVA. MATHEMATICAL MODEL OF INCLINOMETER BASED ON THREE-AXIS MICROELECTROMECHANICAL ACCELEROMETER

<u>Key words:</u> MEMS accelerometer, Euler angles, inclinometer, angular deviation module.

The aim of the work is to develop a mathematical model of a device that measures angular deviation of an object from a given angular orientation based on digital three-axis microelectromechanical accelerometer. The model inputs are arrays of two Euler angles – roll and pitch – describing the dynamics of angular position of the object under consideration. The article contains analytical expressions that describe the signals of three-axis micro-electromechanical accelerometer imitator with digital outputs, and consider the presence of constant offsets, the difference of scale factors along sensitivity axes, flicker noise of the sensor, as well as quantization effects. An algorithm for calculating the modulus of average angular deviation $\Delta\alpha_{avrg}$ from a given angular orientation during the observation period is considered. The choice of minimum digit capacity of analog-to-digital converter of the accelerometer is justified. The authors show that if certain conditions are met (maximum modulo element of constant offsets vector is not more than 0.03), it is possible to ignore the calibration procedure of three-axis accelerometer, if valid relative measurement error is not higher than 5 %.

V. G. ANDREEV, V. T. DMITRIEV. ALGORITHM FOR JOINT IMPLEMENTATION OF PRIMARY CODEC AND SPEECH MASKER WITH THE POSSIBILITY OF PROTECTING PHONOGRAMS FROM FALSIFICATIONS

<u>Key words:</u> primary codec, speech signal, speech masking, phonogram falsification detection, phonogram recovery, Khurgin – Yakovlev representation modification, reconstructed speech quality, secure transmission systems.

A modification of the Khurgin – Yakovlev representation in joint implementation of codec and masker of speech signals with the ability to protect phonograms from falsification during storage and transmission is proposed to be used. The aim of the work is to develop an algorithm for joint implementation of primary codec and masker of speech signals with the possibility of protecting phonograms from falsifications. The implementation of primary codecs of speech signals based on the modification of the Khurgin – Yakovlev representation makes it possible to increase noise immunity as well as reconstructed speech quality at the output of transmission system, or to reduce transmission rate with the same quality, to provide simpler implementation of synthesizing fil-

ters, and to realize the possibilities of parallel processing. The possibility of joint implementation based on primary codec, masking algorithms as well as an algorithm for detecting falsified phonograms and recovering falsified phonograms based on a modification of the Khurgin – Yakovlev representation is shown.

V. T. DMITRIEV, A. A. BAUKOV. DEVELOPMENT OF THE ALGORITHM FOR IMPROVING VIDEO IMAGES CONTRAST TO BE USED IN DIGITAL TELEVISION SYSTEMS

Key words: video processing, contrast, histogram equalization, approximation, objective function minimization, contrast enhancement degree, intensity, color saturation, multi-criteria approach.

The problem of improving the contrast of video images to be used in television systems is considered. Preliminary studies of known methods for solving this problem have been carried out. The aim of the work is to develop an algorithm for increasing contrast, in which the distortions inherent in known approaches are significantly reduced, and the restoration of color brightness characteristics of images exposed to undesirable phenomena that caused the weakening of contrast is also carried out. Statistical analysis of such parameters of low-contrast frame regions as intensity gradient vector mod-ulus and pixel color saturation was performed using the method of minimizing objective function by the Nelder – Mead simplex algorithm. An algorithm for contrast enhancement is proposed, which differs from the known ones by adding stages of automatic assessment of necessary and sufficient degree of contrast increase in various frame areas, intensity correction and color saturation components with transition to HSI color space (Hue, Saturation, Intensity). A multi-criteria approach was used and the resulting quality criterion was introduced, including not only assessment of increase in contrast, but also reference indicators of image restoration, such as indices of structural similarity and mutual in-formation. The authors have established that the proposed algorithm provides an increase in these criteria by 11...21 % and by 3...32 %, respectively, compared with known approaches with similar increase in contrast, and increase in the resulting quality indicator by 6...19 %.

MATHEMATIC AND SOFTWARE COMPUTER SYSTEMS AND COMPUTER NETWORKS

D. A. PEREPELKIN, D. D. TKACHEV. DEVELOPMENT OF GATEWAY AND CLOUD PLATFORM OF SOFTWARE DEFINED NETWORK OF INTERNET OF THINGS DEVICES

Key words: Internet of Things, software defined networks, cloud platform, visual software system, network architecture, UML class diagram.

Currently, Internet of Things technologies are widely used in various fields of activity. The aim of the work is to develop an IoT gateway that provides interaction of IoT devices, collects data from a software defined mesh network of Internet of Things devices and transmits them to a cloud platform for further processing. The cloud platform, in turn, provides storage, processing and analysis of data from Internet of Things devices, as well as provides various services that allow you to monitor the status of devices and manage them. To confirm the effectiveness of the proposed approach, a visual software system IoT Configuration Map has been developed, which allows you to automate the

process of configuring Internet of Things devices, and also displays data from devices and the topology of the mesh network.

S. V. SKVORTSOV, M. S. DYAKOV. ACCELERATION OF GENETIC ALGORITHM FOR TRANSPORTATION PROBLEM SOLUTION BY MEANS OF MULTITHREADING PROGRAMMING

Key words: transportation problem, genetic algorithm, selection, crossover, mutation, sequential algorithm, multithreading, graphics processing unit.

The application of a genetic algorithm for solving a transportation problem according to cost criterion is studied. The aim is to organize parallel processes in the implementation of basic genetic operators, aimed at accelerating the operation of genetic algorithm. Possible approaches to the implementation of multithreaded applications for solving a transportation problem based on a genetic algorithm using modern programming technologies are presented. A computational experiment was per-formed to evaluate the acceleration of a genetic algorithm when processing large populations using CUDA and OpenMP multithreading programming technologies. The features of Linux operating system architecture related to data buffering when accessing computer memory are investigated, the use of which also makes it possible to increase the efficiency of genetic algorithm when processing large populations. Experimental estimates of a multithreading application acceleration based on OpenMP technology achieved by programmatically disabling data buffering are obtained.

INTELLIGENT INFORMATION SYSTEMS
AND TECHNOLOGIES

I. YU. KASHIRIN. KNOWLEDGE MODELS TO CORRECT DATA DRIFT IN DATA MINING

Key words: data drift, ML-models, data mining, forecasting accuracy, knowledge base, semantic networks, ontological knowledge models, hierarchical numbers.

The article contains a description of a new method for determining and correcting data drift in machine learning models (Machine Learning, ML-models). Data drift is a negative change over time in the patterns of forming the basic features of initial training, test and validation data sets that worsen prediction accuracy characteristics of ML models in Data Mining concept.

Existing methods for detecting and correcting data drift, drift varieties are considered, the problem of deep semantic changes in data caused by dynamics peculiarities of main concepts and relations in the subject area of ML-models application is formulated.

A new drift correction method is the basis of a new technology to design classification, regression and forecasting models for specifically formalized subject areas. When choosing the scope of "sliding window", first of all, the structure of domain knowledge model is taken into account, which can use ontological representation of Semantic Web concept. Input features of training data set are grouped according to the structure of concepts and relationships in knowledge base. Alternative paradigmatic relations where local study is carried out on the drift of semantic features corresponding to the chosen paradigm are tracked.

As an example for experimental part of the study, the subject area of communication services was chosen, the data source of which is the international Kaggle repository. Software implementation was performed using Spider v.4 toolkit in Python v.3.8. The results of the experiments performed show the effectiveness of a new method and technology for data drift correction with obtaining qualitatively new possibilities for automatic data analysis.

The aim of the work is to present a new method for determining and correcting data drift, as well as the corresponding technology, allowing the use of automatic search, monitoring and correction of data sets in their temporal development.

Y. B. SHCHENEVA, A. N. PYLKIN, E. S. SHCHENEV, O. A. BODROV. A MODEL FOR DEVELOPMENT OF EDUCATIONAL COMPETENCIES USING DATA MINING TOOLS

Key words: educational competencies, integrated approach, multidimensional space, private and generalized indicators, metric, competence development trajectories, cluster analysis, intellectual data analysis.

The article considers the problem of constructing a model to develop educational competencies using methods of data mining technology. The aim of the article is to develop integrated approach that includes data analysis technology using multidimensional representation concept and cluster analysis methods. Classification and particular indicators ordering methods determining the level of educational competencies development are considered. Metric choice is justified by obtaining generalized indicator in n–dimensional space. The approach to construct educational competence development trajectories and methods to choose approximations are explained, the algorithm and the choice of clustering method for effective assessment of educational process quality are substantiated based on analyzed indicators results.

MATHEMATICAL AND COMPUTER MODELING

V. P. KORYACHKO, V. A. MINAEV, R. O. STEPANOV, A. O. FADDEEV. MODELING OF SEISMIC RISKS ON CRITICAL INFRASTRUCTURE OBJECTS LOCATION TERRITORIES

Key words: mathematical modeling, seismic risk, gravity field anomalies, geodynamic hazards, stresses and displacements, geological environment, earthquakes.

The article presents a mathematical technology for assessing the places of possible geodynamic disasters occurrence, in particular, earthquakes, based on the analysis of geodynamic instability, namely, horizontal gradients of gravitational field anomalies in isostatic reduction. The aim of the article is to create a system of mathematical models that form the basis of seismic risk assessment technology. Special attention is paid to probabilistic mathematical model of seismic risk assessment based on the representation of possible geodynamic states of geological environment as the simplest event flow. The main results in practical implementation of mathematical models of seismic risk assessment developed by the authors on the examples of the Baikal region, the territories of the north of Japan and the Russian Far East are presented and considered.

K. V. BUKHENSKY, A. N. KONYUKHOV, A. B. DUBOIS, D. O. POPOVA, S. S. SEMINA. FULLY FUZZY REGRESSION INADEQUATE OLS ESTIMATORS CORRECTION VIA ROTATION TRANSFORMATIONS

Key words: fuzzy set, LR-type fuzzy number, membership function, shape function, α-cut, fully fuzzy regression, α-cut ordinary least squares.

The aim of the work is to apply rotation transformations for the correction of inadequate OLS estimators of single factor fully fuzzy regression (FFR). In this paper the estimator is supposed to be inadequate if at least one of the following takes place: 1) fuzzy slope has no particular sign; 2) fuzzy slope or intercept are non-convex fuzzy sets (FSs); 3) negative spreads occur. The first case means violation of calculation assumptions made a priori. Two subsequent cases are in contradiction to fuzzy numbers (FNs) axioms. The method proposed includes the analysis of FFR's coefficients of α-cut OLS estimators for the inadequacies mentioned above and their removal via rotation transformations of different coordinate planes in six-dimensional structural parameter space of input and output variables, being triangular FNs (two modal values and four spreads). The numerical experiments show that the technique proposed ensures empirical and predicted FNs shape functions identity and leads to significant approximation root mean square error (RMSE) drop calculated in original conditions.

V. P. KORYACHKO, S. S. RUMYANCEV, L. V. ARONOV. REFLECTOMETRIC LEVEL GAUGE FOR MEASURING WATER LEVEL IN NUCLEAR POWER PLANT CIRCUIT MATHEMATICAL MODEL

Key words: reflectometric level gauge, pulsed reflectometer, mathematical model, nuclear power plant, computer model, SimInTech.

A mathematical model of pulsed reflectometric level gauge is constructed, which takes into account in-homogeneities in the path of probing signal in microwave tract. A computer model was implemented in SimInTech dynamic simulation environment. The mathematical model is universal, which makes it possible to introduce additional inhomogeneities and study the influence of probing pulse temporal parameters: duration, period, and duty cycle. In addition, the authors propose a method to compensate for the influence of temperature and pressure in primary circuit of nuclear power plant on the accuracy of measuring the coolant level by introducing additional reference marks in the sensitive element of pulsed reflectometric level gauge.

SYSTEM ANALYSIS, MANAGEMENT AND INFORMATION PROCESSING

A. I. NOVIKOV, V. A. OVCHINNIKOV. ITERATIVE ALGORITHM FOR FILTERING PERIODIC NOISE OF DIGITAL IMAGES

Key words: periodic noise, discrete Fourier transform, amplitude spectrum, iterative algorithm, frequency rectangle, variance estimation.

The aim of the work is to develop and experimentally test a fully automatic iterative algorithm for filtering periodic noise of a digital image based on two-dimensional discrete Fourier transform (DFT). The algorithm is based on the idea of sequential refinement of

geometry and sizes of regions in the vicinity of local extremes points of amplitude spectrum corresponding to periodic noise frequencies. The estimation of amplitude spectrum dispersion with correctly «cut out» frequency coefficients should be close to amplitude spectrum dispersion of the image free from periodic noise. This property of the spectra is the basis for the criterion to stop iterative process. Studies of the results of filtering periodic noise in the form of horizontal, vertical, diagonal stripes on the image and their combinations have been carried out.

A. I. BOBIKOV, M. D. KORNIENKO. OPTIMAL NON-STATIONFRY CONTROL OF MULTIPLY CONNECTED OBJECTS

Key words: low control, mobile robot, non-stationary systems, desired trajectory, smooth function of time, rectilinear and rotational motions, non-stationary smooth convex optimization problem, global asymptotic convergence, performance criterion gradient.

We consider the problem of motion planning and control, a well-known problem in the field of robotics. The aim of the work is to determine, with respect to robot dynamics, the optimal trajectory of its motion, which is planned or desired trajectory. Then, taking this trajectory as the desired reference action, we find control laws of mobile robot, allowing to track the optimal solution with required accuracy. The trajectory can be either smooth or non-smooth. For non-smooth motion trajectory, the methodology for determining the trajectory is reduced to the selection of reference transfer function. Such a method leads to a solution that coincides with the classical methods for solving a similar problem without the use of optimization methods, if setting effect is a smooth function of time. However, in the presence of obstacles, the desired trajectory of robot motion in a number of cases consists of several segments corresponding to rectilinear and rotational motions, which causes the non-stationary nature of trajectory as a piecewise continuous function of time.

BIOMEDICAL INFORMATION SYSTEMS

A. V. GORBUNOV, E. N. TYGOLUKOV, A. V. NEPROKIN, P. A. PALATOV. BIOMEDICAL DATA MONITORING SYSTEM FOR CARDIOVASCULAR RISK PREDICTION

Key words: cardiovascular risk factors, information system, system for combined analysis of dizziness.

The aim of the work is to develop information system for predicting cardiovascular disease risk. Common approaches to cardiovascular disease risk assessment are described, as well as the factors taken into account during examination of a patient. An algorithm and its implementation based on C# programming language have been created which is designed to simplify a doctor's work when analyzing patient's data. The system takes into account anthropometric, biochemical, morphological, physiological comorbidities and social risk factors. Selected risk factors are listed in many national recommendations of different countries in Europe, USA and Russia. Program implementation incorporates the actual problem of comorbid disorders, with the possibility of additional

analysis of epileptic activity parameters and oculomotor disorders obtained using the system of combined study of dizziness, which allows analyzing mutual influence of CVD, neurological disorders and vestibular disorders.

PHYSICAL ELECTRONICS AND NANOELECTRONICS

E. YU. GRACHEV. X-RAY DETECTOR FOR DIGITAL RADIOGRAPHY INSTALLATIONS OF ELECTRONICS DEVICES

Key words: digital X-ray detector, microfocus X-ray tomography, digital radigraphy, CMOS camera, basic spatial resolution, modulation transfer function.

The creation of x-ray image detector for the installation of digital radiography is considered. The aim of the work is to design X-ray image detector with active area of about 100x100 mm. In order to reduce the dose load on detector electronic components, optical decoupling based on a mirror and a scintillation screen spaced apart in space is used. The calculation of detector optical scheme is carried out and necessary parameters of digital camera and focusing lens are determined. Three-dimensional CAD model of the detector was developed and an experimental model was made. Techniques for the experimental determination of parameters and characteristics of the detector are given. Basic spatial resolution of the detector is determined, the value of signal-to-noise ratio of images is estimated, and modulation transfer functions are constructed.

N. V. RYBINA, N. B. RYBIN, V. V. TREGULOV, G. N. SKOPTSOVA. STUDY OF HEAT TREATMENT MODES INFLUENCE ON INFORMATION-CORRELATION PROPERTIES OF POROUS SILICON FILM SURFACE

Key words: porous silicon, metal-assisted etching, thermal annealing, diffusion, scanning electron microscopy.

The results of studying the influence of thermal annealing and diffusion on information-correlation properties of porous silicon films surfaces formed by metal-assisted etching on a single-crystal silicon substrate are presented. Studies of porous silicon film surface were carried out by scanning electron microscopy, two-dimensional detrended fluctuation analysis, and average mutual information. According to the research results, heat treatment regimes are shown to affect morphology features of porous silicon films in micron and submicron scales.

V. V. TREGULOV, G. N. SKOPTSOVA, N. V. RYBINA, N. B. RYBIN. THE EFFECT OF THERMAL ANNEALING OF SEMICONDUCTOR STRUCTURE WITH POROUS SILICON FILM ON MECHANISMS OF CARRIER TRANSFER

Key words: porous silicon, metal-assisted etching, thermal annealing, current-voltage characteristics, capacitance-voltage characteristics, traps, charge carrier transfer.

The results of studying the effect of thermal annealing of semiconductor structure with porous silicon film on the features of charge carrier transfer processes and trap concentration are presented. A porous silicon film was grown by metal-assisted etching. The studies were carried out by the methods of current-voltage and capacitance-voltage

characteristics. Upon annealing in temperature range of 700 – 900 ºC for 10 min, the concentration of traps is shown to decrease by more than two orders of magnitude. As annealing temperature increases, rectifying properties of semiconductor structure deteriorate. Also, as a result of annealing, the influence of currents limited by space charge on the mechanisms of charge carrier transport increases.

A. N. VLASOV. SHARPENING OF REAR FRONT OF QUASI-SPARK DISCHARGE IN PULSED PLASMATRON

Key words: pulsed plasmatron, toroidal plasma vortex, quasi-spark discharge, electro-explosive current interrupter, pulsed magnetic field, induction discharge.

The possibility of sharpening the rear front of quasi-spark discharge which creates a magnetic field pulse in a pulsed plasmatron with induction discharge excited in a toroidal plasma vortex in semi-open cylindrical chamber on the side wall of which electrically exploding wires are placed, and near the opposite ends – cathode and anode connected to a capacitive storage is considered. The sharpening of rear front is achieved by including electro-explosive current interrupter in anode circuit. The aim of the work is to estimate the duration of trailing edge for quasi-spark discharge when using electro-explosive current interrupter and to calculate the cross section of the conductor used in it, as well as to experimentally verify the results of the calculations.

B. A. KOZLOV, D. S. MAKHANKO. SWITCHING TIMES OF SPARK GAPS-SHARPENERS AT PRESSURE UP TO 140 ATMOSPHERE

Key words: spark gap, spark gap-sharpener, spark discharge development time, switching time, static breakdown in gas, gas pressure, breakdown voltage, interelectrode distance.

Characteristic switching times of spark gaps-sharpeners for the breakdown voltage range of $100 \div 400$ kV are determined. The aim of this work is to obtain quantitative information about the switching times of spark gaps-sharpeners in the previously unstudied pressure range from 20 to 140 atmospheres under static breakdown conditions. Based on the most developed theoretical models for the development of a spark discharge for pressures of $1 \div 10$ atmospheres, quantitative information was obtained on the characteristic values of switching times in pressure range from 20 to 140 atmospheres. General tendency for the reduction of discharge development time proportionally to pressure increase has been established. Experimentally measured switching times of spark gaps-sharpeners of RO-48 type (breakdown voltage 150 ± 2 kV, hydrogen pressure in spark gap-sharpener $55 \div 58$ atm, interelectrode gap 0.3 cm) have values within $\sim 230 \dots 250$ picoseconds at the level $(0.1 \div 0.9)$ of breakdown voltage.

A. V. KOSTIN. DEVELOPMENT OF SIMPLIFIED TECHNIQUE FOR DETERMINING THE WIDTHS OF METAL-BASED PRINTED CIRCUIT BOARD CONDUCTORS OPERATING IN SPACE VACUUM

Key words: printed circuit board, printed conductor, width, space vacuum, temperature, technique, overheating, layer, heat flows.

The article describes the work aimed at developing a more universal technique for determining the width of printed conductors of metal-based circuit boards operating in space vacuum. To achieve this, the following tasks were solved: a simplified mathematical model was developed to achieve universality; graphs were constructed to determine the width of printed conductors that are not tied to layers layout; an assessment error in determining the width of printed conductors by means of analyzing the deviation of overheating temperature associated with technique universalization was carried out. The relevance of the work is related to the need to choose the width of printed conductors in question in the process of designing onboard spacecraft equipment. Thus, a more universal method for determining the width of printed circuit conductors of metal-based boards operating in space vacuum, not tied to layers layout has been developed..