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10th IEEE EAST-WEST DESIGN & TEST SYMPOSIUM (EWDTS 2012)

Kharkov, Ukraine, September 14-17, 2012

The main target of the **IEEE East-West Design & Test Symposium** (EWDTS) is to exchange experiences between scientists and technologies of Eastern and Western Europe, as well as North America and other parts of the world, in the field of design, design automation and test of electronic circuits and systems. The symposium is typically held in countries around the Black Sea, the Baltic Sea and Central Asia region. We cordially invite you to participate and submit your contributions to EWDTS'12 which covers (but is not limited to) the following topics:

- Analog, Mixed-Signal and RF Test
- Analysis and Optimization
- ATPG and High-Level Test
- Built-In Self Test
- Debug and Diagnosis
- Defect/Fault Tolerance and Reliability
- Design for Testability
- Design Verification and Validation
- EDA Tools for Design and Test
- Embedded Software Performance
- Failure Analysis, Defect and Fault
- FPGA Test
- HDL in test and test languages
- High-level Synthesis
- High-Performance Networks and Systems on a Chip
- Low-power Design
- Memory and Processor Test
- Modeling & Fault Simulation
- Network-on-Chip Design & Test
- Modeling and Synthesis of Embedded Systems
- Object-Oriented System Specification and Design
- On-Line Testing
- Power Issues in Design & Test
- Real Time Embedded Systems
- Reliability of Digital Systems
- Scan-Based Techniques
- Self-Repair and Reconfigurable Architectures
- Signal and Information Processing in Radio and Communication Engineering
- System Level Modeling, Simulation & Test Generation
- System-in-Package and 3D Design & Test
- Using UML for Embedded System Specification
- CAD and EDA Tools, Methods and Algorithms
- Design and Process Engineering
- Logic, Schematic and System Synthesis
- Place and Route
- Thermal, Timing and Electrostatic Analysis of SoCs and Systems on Board
- Wireless and RFID Systems Synthesis
- Digital Satellite Television

The Symposium will take place in Kharkov, Ukraine, one of the biggest scientific and industrial center. Venue of EWDTS 2012 is Kharkov National University of Radioelectronics was founded 81 years ago. It was one of the best University of Soviet Union during 60th - 90th in the field of Radioelectronics. Today University is the leader among technical universities in Ukraine.

The symposium is organized by Kharkov National University of Radio Electronics and Science Academy of Applied Radio Electronics http://anpre.org.ua/ in cooperation with Tallinn University of Technology. It is technically co-sponsored by the IEEE Computer Society Test Technology Technical Council (TTTC) and financially supported by Trades Committee of Kharkov National University of Radioelectronics and Trades Committee of Students, Aldec, Synopsys, Kaspersky Lab, DataArt Lab, Tallinn Technical University.

CONTENTS

An Efficient Fault Diagnosis and Localization Algorithm for Successive-Approximation Analog to Digital Converters
Melkumyan T., Harutyunyan G., Shoukourian S., Vardanian V., Zorian Y. **15**

Application of Defect Injection Flow for Fault Validation in Memories
Amirkhanyan K., Davtyan A., Harutyunyan G., Melkumyan T., Shoukourian S., Vardanian V., Zorian Y. **19**

SSBDDs and Double Topology for Multiple Fault Reasoning
Raimund Ubar, Sergei Kostin, Jaan Raik **23**

Self Compensating Low Noise Low Power PLL design
Vazgen Melikyan, Armen Durgaryan, Ararat Khachatryan, Manukyan Hayk, Eduard Musaelyan **29**

Optimization Considerations in QCA Designs
Zahra NajafiHaghi, Marzieh Mohammadi, Behjat Forouzandeh, Zainalabedin Navabi **33**

Implementation of Address-Based Data Sorting on Different FPGA Platforms
Dmitri Mihhailov, Alexander Sudnitson, Valery Sklyarov, Iouliia Skliarova **38**

Comparison of Model-Based Error Localization Algorithms for C Designs
Urmas Repinski, Jaan Raik **42**

Synthesis of Clock Trees for Sampled-Data Analog IC Blocks
Bilgiday Yuce, Seyrani Korkmaz, Vahap Baris Esen, Fatih Temizkan, Cihan Tunc, Gokhan Guner, I. Faik Baskaya, Iskender Agi, Gunhan Dundar, H. Fatih Ugurdag **46**

Experiences on the road from EDA Developer to Designer to Educator
H. Fatih Ugurdag **50**

Multi-Beam Constant Modulus Adaptive Arrays in Real-Valued Arithmetic
Victor I. Djigan **54**

Simulation of Total Dose Influence on Analog-Digital SOI/SOS CMOS Circuits with EKV-RAD macromodel
Petrosyants K. O., Kharitonov I. A., Sambursky L. M., Bogatyrev V. N., Povarnitcyna Z. M., Drozdenko E. S. **60**

Models for Embedded Repairing Logic Blocks
Hahanov V.I., Litvinova E.I., Frolov A., Tiecoura Yves **66**

Real-time Interconnection Network for Single-Chip Many-Core Computers
Harald Richter **72**

Invariant-Oriented Verification of HDL-Based Safety Critical Systems
Kharchenko V., Konorev B., Sklyar V., Reva L. **76**

An Improved Scheme for Pre-computed Patterns in Core-based SoC Architecture
Elahe Sadredini, Qolamreza Rahimi, Paniz Foroutan, Mahmood Fathy, Zainalabedin Navabi **80**

Synthesis of Moore FSM with transformation of system in CPLD
Aleksander Barkalov, Larysa Titarenko, and Sławomir Chmielewski 85

A WSN Approach to Unmanned Aerial Surveillance of Traffic Anomalies: Some Challenges and Potential Solutions
David Afolabi, Ka Lok Man, Hai-Ning Liang, Eng Gee Lim, Zhun Shen, Chi-Un Lei, Tomas Krilavičius, Yue Yang, Lixin Cheng, Vladimir Hahanov, and Igor Yemelyanov 91

Synthesis of Qubit Models for Logic Circuits
Wajeb Gharibi, Zaychenko S.A., Dahiri Farid, Hahanova Yu.V., Guz O.A., Ngene Christopher Umerah, Adiele Stanley 95

Theory of Optimal Nonlinear Filtering in Infocommunication's Problems
Victor V. Panteleev 102

Verification of Specifications in the Language L with respect to Temporal Properties Expressible by GR(1) Formulas
Anatoly Chebotarev 110

Properties of code with summation for logical circuit test organization
Anton Blyudov, Dmitry Efanov, Valery Sapozhnikov, Vladimir Sapozhnikov 114

Loop Nests Parallelization for Digital System Synthesis
Alexander Chemeris, Julia Gorunova, Dmiry Lazorenko 118

Decreasing the Power Consumption of Content-Addressable Memory in the Dataflow Parallel Computing System
Levchenko N.N., Okunev A.S., Yakhontov D.E., Zmejev D.N. 122

WebALLTED: Interdisciplinary Simulator Based on Grid Services
Zgurovsky M., Petrenko A., Ladogubets V., Finogenov O., Bulakh B. 126

Malfunctions Modeling of Converters and Homogeneous-chain Distributed Structure Devices
Artur Gulin, Zhanna Sukhinets 130

On structure of quasi optimal algorithm of analogue circuit designing
Zemliak A., Michua A., Markina T. 134

A Neuro-Fuzzy Edge Based Spectrum Sensing Processor for Cognitive Radios
Mohammadreza Baharani, Mohammad Aliasgari, Mohammadreza {Najafi, Jamali}, Hamid Noori 138

Qubit Model for Solving the Coverage Problem
Hahanov V.I., Litvinova E.I., Chumachenko S.V., Baghdadi Ammar Awni Abbas, Eshetie Abebech Mandefro 142

PDF testability of the circuits derived by special covering ROBDDs with gates
Matrosova A., Nikolaeva E., Kudin D., Singh V. 146

Compositional Microprogram Control Unit with Operational Automaton of Transitions
Alexander Barkalov, Roman Babakov, Larisa Titarenko 151

Observability Calculation of State Variable Oriented to Robust PDFs and LOC or LOS Techniques
Matrosova A., Ostanin S., Melnikov A., Singh V. 155

Low-Voltage Low-Power 2.5 GHz Linear Voltage Controlled Ring Oscillator
Hayk H Dingchyan 161

High Speed IC Output Buffer with Reduced Power Consumption
Karine Movsisyan 165

Engineering-Maintenance Methods of the Calculation Service Area Fixed BWA-paths
Sergey I. Myshlyakov, Victor V. Panteleev 170

Analyses of two run march tests with address decimation for BIST procedure
Ireneusz Mrozek, Svetlana V. Yarmolik 176

Design of Area Efficient Second Order Low Pass Analog Filter
Andranik Hovhannisyan 180

Power Consumption Analysis of Content-Addressable Memories
Levchenko N.N., Okunev A.S., Yakhontov D.E. 183

IC Physical Design Optimization Due to Effects of Device Physical Geometries
Avag Sargsyan 187

System-on-Chip FPGA-Based GNSS Receiver
Alexander Fridman, Serguey Semenov 190

Testware and Automatic Test Pattern Generation for Logic Circuits
Victor Zviagin 196

Artificial Neural Network for Software Quality Evaluation Based on the Metric Analysis
Oksana Pomorova, Tetyana Hovorushchenko 200

Self-Compensation of Influence of Parasitic Gate-Drain Capacitances of
CMOS Transistors in Analog Microcircuitry
Sergey G. Krutchinsky, Grigory A. Svizev, Alexey E. Titov 204

Hash-based Detection of OFDM Watermarking Symbol for Radiotelephone Identification
Aleksandr V. Shishkin, Aleksandr A. Lyashko 208

A Novel Wideband Circular Ring DGS Antenna Design for Wireless Communications
Rakesh Sharma, Abhishek Kandwal, Sunil Kumar Khah 211

Universal technique of the analysis of round-off noise in digital filters with
arbitrary structure described by topological matrixes
Vladislav A. Lesnikov, Alexander V. Chastikov, Tatiana V. Naumovich, Sergey V. Armishev 215

Hardware Reduction for Compositional Microprogram Control Unit Dedicated for CPLD Systems
Barkalov A., Titarenko L., Smolinski L. 219

Conservative Finite-difference Scheme for the Problem of Laser Pulse Propagation
in a Medium with Third-order Dispersion
Vyacheslav A. Trofimov, Anton D. Denisov 225

A Four Bit Low Power 165MSPS Flash-SAR ADC for Sigma-Delta ADC Applications
Hasan Molaei, Khosrow Hajsadeghi 229

Matrix Implementation of Moore FSM with Nonstandard Presentation of State Codes
Titarenko L., Hebda O. 233

Alowpower1.2GS/s4-bitflashADCin0.18mCMOS
Mohammad Chahardori, Mohammad Sharifkhani, Sirous Sadughi 237

Symmetrical Differential Stages on CMOS Transistors with Circuits ofSelf-Compensation and Cancellation
Sergey G. Krutchinsky, Grigory A. Svizev, Alexey E. Titov 241

Lower Bound of Error in AOA Based Passive Source Localization Using Single Moving Platform
Hejazi F., Norouzi Y., Nayebi M.M. 245

A Design for Testability Technique for Quantum Reversible Circuits
Joyati Mondal, Debesh K. Das, Dipak K. Kole, Hafizur Rahaman 249

A Flexible Design for Optimization of Hardware Architecture in Distributed Arithmetic based FIR Filters
Fazel Sharifi, Saba Amanollahi, Mohammad Amin Taherkhani, Omid Hashemipour 253

Models for Quality Analysis of Computer Structures
Murad Ali Abbas, Chumachenko S.V., Hahanova A.V., Gorobets A.A., Priymak A. 258

Expanding Wireless Bandwidth in a Power-Efficient Way:
Developing a Viable mm-Wave Radio Technology
Daniel Foty, Bruce Smith, Saurabh Sinha, Michael Schröter 264

Sampling Theorem for Finite Duration Signal in Limited Frequency Band
Gamlet S. Khanyan 270

SiGe HBT Performance Modeling after Proton Radiation Exposure
Konstantin Petrosyants, Maxim Kozhukhov 274

Classical Models of Test used in Advanced Electronics Quality Assurance
Surendra Batukdeo 278

The Use of Natural Resources for Increasing a Checkability of the Digital Components in Safety-Critical Systems
Drozd A., Kharchenko V., Antoshchuk S., Drozd J., Lobachev M., Sulima J. 283

New version of Automated Electro-Thermal Analysis in Mentor Graphics PCB Design System
Petrosyants K.O., Kozynko P.A., Kharitonov I.A., Sidorov A.V., Chichkanov Y. N. 289

An Approach to Testing of Planar Integrated Antennas in Frequency Range of 5–7 GHz
Aleksandr Timoshenko, Ksenia Lomovskaya, Victor Barinov, Andrey Tikhomirov 293

Optimal project solution decision making in telecommunication systems using multicriteria optimization methods
Valery Bezruk, Alexander Bukhanko 298

Software implementation and debugging of forward error correction codes
Alexey Smirnov, Danila Migalin, Ilya Muravyev, Leonid Pertsev 303

Architecture of Built-In Self-Test and Recovery Memory Chips
Andrienko V.A., Moamar Diaa, Ryabtsev V.G., Utkina T.Yu. 307

The methods of exclusion of variables in symbolic time models of linear periodically time-variable circuit
Yuriy Shapovalov, Dariya Smal 311

Two-Component Encoding of Approximating Picture Pixels in Telecommunication Facilities
Barannik V., Dodukh A., Safronov R. 315

Development of parameterized cell using Cadence Virtuoso
Vadim Borisov 319

Simulation Methods of Diffusion Alloying Process by Means of Taurus TSUPREM-4 Programme
Lagunovich N.L., Borzdov V.M. 321

Control and Diagnosis by Complexity Indicators of System Functioning Process
Tverdokhlebov V.A. 323

Features of the Transfer of Information with Different Reliability in a Single Channel
Alexander Bakhtin, Leonid Pertsev, Olga Timofeeva 327

Construction of Signals with Controlled Peak-Factor
Koshevyy V. M., Dolzhenko D.O. 330

The Effective Method of Space Filtering of Noise in Rayleigh Communication Channel with the Adaptive Antenna
Maistrenko G. V., Rybalko A. M., Shokalo V. M., Strelnitskiy A. A. 333

A New Structure for Interconnect Offline Testing
Somayeh Sadeghi-Kohan, Shahrzad Keshavarz, Farzaneh Zokaee, Farimah Farahmandi, Zainalabedin Navabi 336

Researching of Mathematical Models Based on Optimal Control Approaches for Congestion Control in Telecommunication Network
Lemeshko A.V., Semenyaka M.V. 341

Higher Order Propagation Modes Error and Its Compensation
Zaichenko O. B., Klyuchnyk I. I., Martynenko L. G. 345

Strategy of analyzing most common algorithms for path finding in discrete labyrinth using software statistic data collector
Krasnov Evgeniy, Dmitry Bagaev 349

Method of Implementation of Technology of Orders Based Transparent Parallelizing for Solving Computationally Complex Problems on Cluster
Vitaliy D. Pavlenko, Viktor V. Burdejnyj, Sergey V. Pavlenko 353

Scheduling Tests for 3D SoCs with Temperature Constraints
Indira Rawat, Gupta M.K., Virendra Singh 356

Automated application mapping into Network-on-Chip topologies
Bykov S. O. 360

MIMO Radar with Phase-coded waveforms
Amirsadegh Roshanzamir, Bastani M. H. 363

BBN-based Approach For Assessment of Smart Grid And Nuclear Power Plant Interaction
Eugene Brezhnev, Vyacheslav Kharchenko 367

Design, Test and Fault Detection in QCA 4-to-1 Multiplexer
Zahra NajafiHaghi, Behjat Forouzandeh 374

The Evaluation of Statistical Characteristics of the Retransmission Meter Signal Frequency and Initial Phase on the Basis of VHDL-model
Dmitry A. Velychko, Iegor I. Vdovychenko 378

A Research of Heuristic Optimization Approaches to the Test Set Compaction Procedure Based On a Decomposition Tree for Combinational Circuits
Valentina Andreeva, Kirill A. Sorudeykin 382

Power Reduction of 7T Dual-Vt SRAM Cell Using Forward Body Biasing
Sahba Sabetghadam Jahromi, Raziyeh Bounik 388

VLSI: An Investigation into Electromagnetic Signatures (EMS) for Non-Invasive Testing and Signal-integrity Verification
Kadim HJ, Coulibaly L. M. 392

Secure Data over GSM based on Algebraic Codebooks
Kazemi R., Nashtaali D., Boloursaz M., Behnia F. 397

Simulation of Telecommunication Channel Using Volterra Model
Vitaliy D. Pavlenko, Viktor O. Speranskyy 401

Extracting Complete Set of Equations to Analyze VHDL-AMS Descriptions
Arezoo Kamran, Vahid Janfaza, and Zainalabedin Navabi 405

A Data Modem for GSM Adaptive Multi Rate Voice Channel
Boloursaz M., Hadavi A. H., Kazemi R., Behnia F. 409

Trends and prospects of development of techniques for extracting acoustic sounding information of the atmospheric boundary layer
Klyuchnik I., Panchenko A., Umyarov R. 413

Decision-Making in Robotics and Adaptive Tasks
Tsymbal A.M., Bronnikov A.I. 417

Design of Nonvolatile Memory Based on Magnetic Tunnel Junction for Special Electronic Systems
Aleksandr Kostrov, Vladislav Nelayev, Viktor Stempitsky, Anatoly Belous, Arkady Turtsevich 421

Improving the Dependability of a Water Supply System via a Multi-Agent based CPS
Teodora Sanislav, Liviu Miclea, Paolo Prinetto 425

Cyber Security Lifecycle and Assessment Technique for FPGA-based I&C Systems
Illiashenko Oleg, Kharchenko Vyacheslav, Kovalenko Andriy 432

FPGA Technologies in Medical Equipment: Electrical Impedance Tomography
Perepelitsyn Artem, Shulga Dmitry 437

A Trend-based Design Space Exploration of Multi-core Systems Using Regression Modeling
Fazeleh Hajari Taheri, Omid Fatemi 441

Synchronous Rectifiers Enable High Efficiency for Buck-Boost Converter
Yurii Shynkarenko and Igor Klyuchnyk 445

Test Data Compression Strategy While Using Hybrid-BIST methodology
Elmira Karimi, Mohammad Hashem Haghbayan and Mahmood Tabandeh 449

Self-Adaptive Mobile Wireless Hotspot Zones
Yanovsky M., Kharchenko V., Gorbenko A. 454

The Systolic Compositions of Two-dimensional and Multidimensional Lattice Filters for Space-Time Signal Processing
David I. Lekhovytskiy, Andrii V. Semeniaka, and Dmytro S. Rachkov 458

Power Efficient Implementation of Homogenous Multi-Core Processors
Aram Poghosyan 462

Assertion Based Method of Functional Defects for Diagnosing and Testing Multimedia Devices
Vladimir Hahanov, Karyna Mostova, Oleksandr Paschenko 465

Improved Scaling-Free CORDIC algorithm
Leonid Moroz, Taras Mykytiv, Martyn Herasym 470

Coding Tangible Component of Transforms to Provide Accessibility and Integrity of Video Data
Barannik V.V., Hahanova A.V., Krivonos V.N. 475

Review of the botnet detection techniques
Oleg Savenko, Sergiy Lysenko, Kryshchuk Andrii 479

MEMS Intellect Multiprobes Contacting Devices for Electrical Checking-up of Multilayers Commutative Boards and BGA/CSP Electronic Components
Nevliudov I.Sh., Palagin V.A., Razumov-Frizjuk E.A., Zharikova I.V. 483

Internet of Things: A Practical Implementation based on a Wireless Sensor Network Approach
Michele Mercaldi, Andrea D'Oria, Davide Murru, Hai-Ning Liang, Ka Lok Man, Eng Gee Lim, Vladimir Hahanov, Mischenko Alexander 486

Investigation of EM Wave Propagation of the Wireless Capsule in Human Body
Eng Gee Lim, Zhao Wang, Jin Hui Chen, Tammam Tillo, Ka Lok Man 490

Using pyroelectric detectors in the design of temperature measuring devices
Bondarenko A.Yu, Klyuchnik I.I. 494

Transaction Level Model of Embedded Processor for Vector-Logical Analysis
Irina V. Hahanova, Volodymyr Obrizan, Alexander Adamov, Dmitry Shcherbin 497

Embedded Intelligent Control Systems on the Basis of Elementary Fuzzy-Logic Cells
Dontsova A., Vassiliev A.E. 502

Interconnection Analysis of the Integral Reliability Characteristics of the Monoergative Computer System and User's Competency
Krivoulya G., Shkil A., Kucherenko D. 505

System approach to determination of ADC parameters
Knyshev Ivan 511

Methodological Aspects of Complex Ecological Estimation of Man-Caused Territory State and Mathematical Modelling of Processes in a Environment System
Kozulia T. V., Sharonova N. V. , Emelianova D. I., Kozulia M.M. 514

Method for “Failure on Demand” Latent Faults Diagnosis of NPP Safety Control Systems
Gerasymenko K.E. 519

Informational Saturation of Noise Signals
Kolodiy Z. A., Kolodiy A.Z. 523

The Positional Structural-Weight Coding of the Binary View of Transformants
Barannik V., Krasnoruckiy A., Hahanova A. 525

Synchronization of a Fuzzy Automata
Speranskiy Dmitriy 529

Models for SoC Infrastructure of Radio Frequency Identification with Code-Division Multiple
Filippenko I.V., Hahanova I.V., Filippenko I.O, Maksimov M., Chugurov I. 535

Factorization of Rhythmograms Parametric Spectra on the Base
of Multiplicative Linear Prediction Models
Nataliia V. Kudriavtseva, Iryna O. Fil 538

Logi-Thermal Analysis of Digital Circuits Using Mixed-Signal Simulator Questa ADMS
Petrosyants K.O., Rjabov N.I. 541

Method of Hybrid Regression Analysis in the Calibration Experiments
Ordinartseva N. P. 545

Keynotes speeches and Invited Reports 548

AUTHORS INDEX 554

Higher Order Propagation Modes Error and Its Compensation

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Abstract

The physical and mathematical and metrological model of higher order propagation modes in multiprobe microwave multimeter with three sensors was composed. The higher order propagation modes error estimation, which is proposed, minimizes error by shifting sensors from the middle of the waveguide broad wall to the periphery, without changing the distance between the sensors along the direction of energy propagation through the waveguide.

1. Introduction

Despite the efforts of specialists in the manufacture of generating units, all such devices until now generate not only the useful signal, but also higher order propagation modes [2]. To reduce power level of higher order propagation modes usually use filters [1], but their disadvantage is the high cost and complexity.

The issue of determination of higher order propagation modes spectrum are devoted such fundamental works as [4] (Fig. 1) and [3] Tabl 1. Fig. 1 shows the relationship between higher order propagation modes for a waveguide section 90x45mm. Table 1 shows the quantitative estimation of the spectrum, which will be used in the simulation. Interest in this subject is not weakened, and so far [5] since for great variety of practical applications this problem has great importance. For example, in the process of drying and heating operations, especially practical value has the ability to measure the power of wave types, which will allow to create a uniform distribution of power flux density of the heated object by adjusting the intencity the individual types of waves.

In our view this area is sufficiently investigated, but metrological direction is remained little studied. Meanwhile, there is the prospect of more accurate measurements, in particular, the microwave passing power multiprobe method, which led to interest in this important topic.

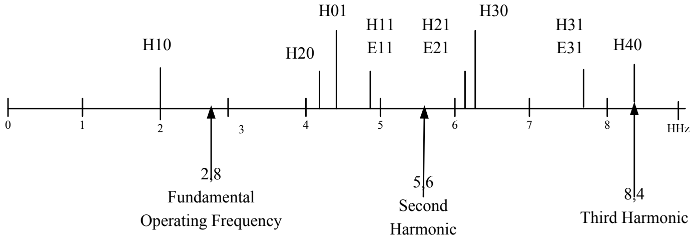

Fig. 1. The critical frequency of the waves in a rectangular waveguide 90 x 45 mm.

As can be seen from Fig. 1 for the second time harmonic modes H20, H01, H11, H30, E11, E21are present.

Table 1. Following harmonic spectrum is typical for M-413 klystron [3]

modes	Fundamental Operating frequency 2856 MHz	Second Harmonic 5712 MHz	Third Harmonic 8568 MHz
H10	31 10	11,206	0,269
H20		1,130	1,490
H01		52,570	0,754
H11		50,643	0,188
E11		8,261	0,450
H21			0,258
E21			0,174
H30			0,138
H31			0,093
E31			0,037
H40			0,042
Total	31 (0 dB)	123,810 (-24 dB)	3,894 (-39 dB)

2. Physical and Mathematical Model of Higher Orde[illegible]es

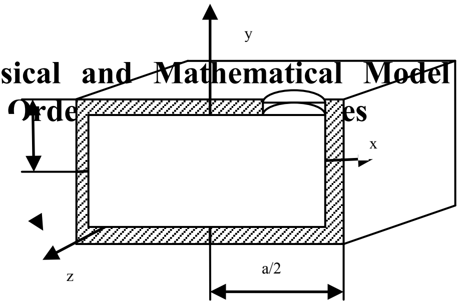

Fig. 2 The coordinate system in a rectangular waveguide

It is proposed a system of coordinates, the origin of that lies on the axis of the waveguide.

As we know the generator stipulates the signal level, frequency range and the presence of harmonics. Mismatched load leads to the appearance of the reflected wave in the microwave tract. The degree of mismatch is quantitatively characterized by modulus Γ and phase φ of complex reflection coefficient of the load. The reflected wave, adding to the incident wave, formes the standing wave in the tract. Thus the higher order propagation modes, the temporal harmonic generator, the standing wave create a complex structure of the field inside the waveguide, and on its walls [4].

The absorbing cylindrical wall of the constantan is used as sensors. This sensor responds to the magnetic field component.

The components of the magnetic field vectors for the wave type H_{mn}, which is distributed in a rectangular waveguide with the center coordinates, which is located on the axis of the waveguide in the direction to the load as shown in Fig. 2 has the following form [8]

$$H_z^+ = H_{mn}\cos\left[\frac{m\pi}{a}\left(x+\frac{a}{2}\right)\right]\cos\left[\frac{n\pi}{b}\left(y+\frac{b}{2}\right)\right]e^{i(\omega\tau-\beta z)}, \tag{1}$$

$$H_x^+ = i\beta\frac{\chi_m}{\chi^2}H_{mn}\sin\left[\frac{m\pi}{a}\left(x+\frac{a}{2}\right)\right]\cos\left[\frac{n\pi}{b}\left(y+\frac{b}{2}\right)\right]e^{i(\omega\tau-\beta z)}, \tag{2}$$

$$H_y^+ = i\beta\frac{\chi_n}{\chi^2}H_{mn}\sin\left[\frac{m\pi}{a}\left(x+\frac{a}{2}\right)\right]\sin\left[\frac{n\pi}{b}\left(y+\frac{b}{2}\right)\right]e^{i(\omega\tau-\beta z)}. \tag{3}$$

$$H_x^+ = i\frac{\beta}{Z_E}\frac{\chi_n}{\chi^2}E_{mn}\sin\left[\frac{m\pi}{a}\left(x+\frac{a}{2}\right)\right]\cos\left[\frac{n\pi}{b}\left(y+\frac{b}{2}\right)\right]e^{i(\omega\tau-\beta z)}, \tag{4}$$

For waves of type E_{mn}

$$H_y^+ = -i\frac{\beta}{Z_E}\frac{\chi_m}{\chi^2}E_{mn}\cos\left[\frac{m\pi}{a}\left(x+\frac{a}{2}\right)\right]\sin\left[\frac{n\pi}{b}\left(y+\frac{b}{2}\right)\right]e^{i(\omega\tau-\beta z)}. \tag{5}$$

We express the coefficients H_{mn} through the incident power in a waveguide of rectangular cross section

$$H_{mn} = \sqrt{\frac{4(2-\delta_{m0}-\delta_{n0})\left(\frac{\chi\lambda}{2\pi}\right)^2 P}{abZ_0\sqrt{1-\left(\frac{\chi\lambda}{2\pi}\right)^2}}}. \tag{6}$$

where δ_{m0}, δ_{n0} – Kroneker-Kapelli symbol

$$\delta_{mn} = \begin{cases} 1, & at\ m = n; \\ 0, & at\ m \neq n. \end{cases}$$

Similar expression can be obtained for the reflected waves. They differ from the incident wave (1)-(5) by propagation direction (the propagation constant changes its sign to the opposite) and amplitude of the reflected wave is less than incident wave amplitude reflection coefficient Γ times.

For each of the projections the incident wave add reflected wave

$$H_{xmn} = H_x^+ + H_x^-,\ H_{ymn} = H_y^+ + H_y^-,\ H_{zmn} = H_z^+ + H_z^-.$$

For each mode is written likewise projections on the coordinate axes. According to the principle of superposition field can be represented by the following expression

$$H_x^\Sigma = \sum_{mn=1}^{7} H_{xmn},\ H_y^\Sigma = \sum_{mn=1}^{7} H_{ymn},\ H_z^\Sigma = \sum_{mn=1}^{7} H_{zmn}.$$

The sensor reacts to the magnetic field by heating. The surface density of heat sources

$$Q = \frac{\rho\vec{H}\vec{H}^*}{2\Delta},$$

where ρ – spesific resistance

Δ – depth of the skin layer,

$$\Delta = \sqrt{\frac{2}{\omega\mu_0\sigma}}.$$

To determine the distribution of heat sources necessary to calculate the scalar product of vectors of the magnetic field on the surface of an absorbing wall. The product is calculated by expression

$$\frac{(\quad)\qquad(\quad)\qquad(\quad)}{\qquad\qquad\qquad\qquad\qquad\qquad}$$

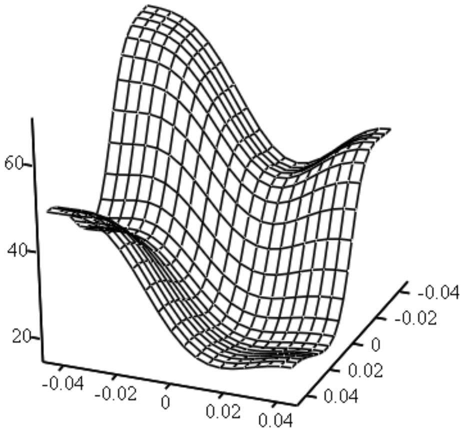

Fig. 4 Surface of error, depending on the displacement of the two sensors relative to the center of the waveguide broad wall

As known, when this iterative method is used, at first we find the coordinates of first approximation solution point X, then the gradient is finded in the point, then a linear function of the coordinates is built, where the coefficients are taken from the gradient at this point. Then the linear function minimum is determine, it gives the corresponding coordinates of Z. New point is calculated from the following expression.

$$X_{K+1} = X_K + \eta(Z_K - X_K),$$

where X_K – coordinates at к iteration;

Z_K – minimum coordinates;

η – step, the value of which ranges from 0 to 1. The correct choice of the step is very important because it influences the convergence of the algorithm as a whole. The novelty is that it is proposed to calculate the step using a graphical method, which greatly simplifies calculations (Fig. 5). The tools of taking the partial derivative using MathCad is used. The derivative of the error should be zero. In this figure, the derivative of the error reaches the zero value at $\eta = 0{,}7$.

4. Conclusion

Both quantitatively and qualitatively the higher order propagation modes error depending on the position sensor across the wall of waveguide was evaluated in this study. It is at least 11% at the optimal placement of sensors at 0.0225 m from the center to the periphery of the waveguide. The error should be considered as a systematic error remnant. And such result can be explained by the superposition of higher order propagation modes structures.

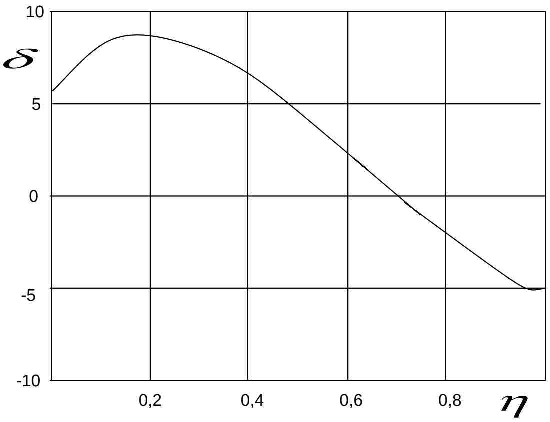

Fig. 5 Determination of the step in the method of Frank-Wolfe

For the case when takes into account fundamental operating frequency, the second and third harmonics of higher order propagation modes the result are analogous, the method of quantitative evaluation of the error remains same.

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