

Thomas Johann Seebecki elektroonikainstituudi 2018. aasta teadus- ja arendustegevuse aruanne

1. Struktuuriüksuse struktuur 2018. a

Thomas Johann Seebecki elektroonikainstituut (edaspidi TJS elektroonikainstituut).

Thomas Johann Seebeck Department of Electronics (hereinafter referred to as the TJS Department of Electronics).

Laur Lemendik, direktor, laur.lemendik@taltech.ee, +372 620 2151.

Instituudi üksused on:

- elektroonika ja sidetehnika õppekeskus (ELSI), õppekeskuse juht Andres Eek, andres.eek@taltech.ee;
- kognitroonika teaduslabor (KOEL), labori juht prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee;
- siduselektronika teaduslabor (SIEL), labori juht dr. Ants Koel, ants.koel@taltech.ee.

Units inside of the department are:

- Study Center for Electronics and Communicative Technologies (StuCen ELSI), head of the study center Andres Eek, andres.eek@taltech.ee;
- Research Laboratory for Cognitronics (BaseLab KOEL), head of the laboratory Prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee;
- Research Laboratory for Communicative Electronics (BaseLab SIEL), head of the laboratory dr. Ants Koel, ants.koel@taltech.ee.

Instituudis tegutsevad järgmised uurimisrühmad:

- pooljuhtelektronika teadusgrupp,
- impedants-spektroskoopia teadusgrupp,
- kognitiivelektronika ja traadita side teadusgrupp.

The department conducts research within 3 research groups:

- Research Group of Semiconductor Electronics,
- Research Group of Impedance Spectroscopy,
- Research Group of Cognitive Electronics and Wireless Communication.

2. Teadus- ja arendustegevuse ülevaade uurimisrühmade lõikes

2.1 Pooljuhtelektroonika teadusgrupp

Uurimisrühma juht: Prof. Toomas Rang, toomas.rang@taltech.ee.

Pooljuhtelektroonika teadusgrupp kuulub siduselektronika teaduslabori koosseisu.

Märksõnad: laia keelutsooniga materjalidest pooljuhtseadised, SiC, materjalide pindnähtused ja siirded, heterosiirded, grafeen, kiiplabori lahendused, metalliseerimistehnoloogiad, difusioonkeevitus, tahkiselektronika, numbrilised eksperimendid.

Teadusgrupp tegeleb uuringutega SiC põhinevate pooljuhtstruktuuride vallas. 2018. aastal uuriti SiC tavastruktuuriga JBS-diodide põhjal vertikaalse arhitektuuriga modulaar-komposiite kasutades ühendustehnoloogiana difusioonkeevitust. Täiustati välise kondensaatorita pinge kordisti prototüüpi, mis kasutab SiC diodide enda mahtuvust (*SiC JBS Diode Symmetrical Voltage Doubler*). Jätkati grafeenil põhinevate multiskalaarsete pindade uurimist leidmaks rakendusi molekulaar-sensorika vallas koostöös St. Peterburi Ioffe Instituudiga. Jätkusid uuringud kiiplaborite tarbeks, et tuvastada patogeene vedelikes. Projektide PUT1435 ja osaliselt IUT1911 raames jätkati numbriliste simulatsioonidega laia keelutsooniga pooljuhtide heterosiirete omaduste ja võimalike defektide uurimiseks. Uurimisgrupi liikmed (dr. Ants Koel, Kaiser Pärnamets, jt) juhivad TJS elektroonikainstituudile olulisi projekte nagu näiteks Tallinna Tehnikaülikooli esimese tudengisatelliidi elektroonikamoodulite disainimeeskonda.

Teadusgrupi peamised teadustöö tulemused 2018. aastal.

1. Läbi numbriliste eksperimentide näitasime, et SiC kristalli pindolekud suurendavad laengukandjate hajumisprotsesse, mille tulemusena väheneb kogu heterostruktuuri päripinge ja suureneb läbilöögipinge.
2. JBS seadiste struktuur, mis on sümbioos pn- ja Schottky siiretest põhjustab kogu siirdemahtuvuse kasvukiiruse muutusele, mis põhjustab väljundpinge suuremale mõjustatavusele sisendpingele tänu täiendavale akumuleeritud laengule erinevates siiretes ja mida tuleb arvestada SiC põhinevate pingekordistite (*stacks*) loomisel;
3. Numbriliste eksperimentide abil demonstreerisime, et grafeeni pindolekute kontsentratsioon on otseses sõltuvuses fenooli ja metanooli molekulide olemasolust keskkonnas, mis viib omakorda grafeeni pindjuhtivuse muudatustele võimaldades rakendada grafeeni selektiivsete sensorite loomisel.
4. Kasutades üldist termilise analüüsi metodoloogiat demonstreerisime NAAT kiiplabori optimaalse energiatarbe vastavust uudse kuumutamiselemendi rakendamisel.
5. Tõestati lineaarse modulatsiooni rakendatavus ning verifitseeriti uudne skeemitehniline ja tehnoloogiline lahendus 200MHz parentatud lineaarsusega programmeeritavale paisuvõimsuse jaoturile kasutades 35nm CMOS tehnoloogiat.

Teadusgrupi peamised arendustöö tulemused 2018. aastal.

1. Valmis prototüüpne lahendus energia haldamiseks kiipidel (J. Mihhailov, M. Koort).
2. Valmis prototüüp *Lab-on-Chip* lahenduses patogeenide tuvastamiseks (T. Pardy ja Firma SelfDiagnostiks GmbH).
3. Loodi tootmiseelne lahend (skeemitehniline platvorm) traadita sidet võimaldavate kiipide tarbeks (V. Kampus, Intel Austria).

4. Disainiti, verifitseeriti ja implementeeriti spetsiifilised riistvaralised lahendused Euroopa kiirendi tarbeks Lundis.

Viidi edukalt läbi rahvusvaheline konverents BEC2018 (A. Koel, F. Rang).

Valik olulisemaid artikleid.

1. Pardy, Tamás; Rang, Toomas; Tulp, Indrek (2018). Thermal Analysis of a Disposable, Instrument-Free DNA Amplification Lab-on-a-Chip Platform. *Sensors*.10.3390/s18061812 .
2. Rashid, M.H.; Koel, A.; Rang, T. (2018). Simulations of heterostructures based on 3C-4H and 6H-4H silicon carbide polytypes. *Materials Science Forum*, 924 MSF, 302–305.10.4028/www.scientific.net/MSF.924.302.
3. Korolkov, Oleg; Land, Raul, Toompuu, Jana; Sleptšuk, Natalja; Rang, Toomas (2018). SiC JBS Diode Symmetrical Voltage Doubler Represented as the Diffusion-Welded Stack. *Materials Science Forum*, 924, 862–865.10.4028/www.scientific.net/MSF.924.862.
4. Rashid, H.; Koel, A.; Rang, T. (2018). Simulations of Propane and Butane Gas Sensor Based on Pristine Armchair Graphene Nanoribbon. *IOP Conference Series: Materials Science and Engineering*, 362: 2018 International Conference on Smart Engineering Materials, ICSEM 2018; Bucharest; Romania; 7 March 2018 through 9 March 2018. Institute of Physics Publishing., (Issue 1).10.1088/1757-899X/362/1/012001.
5. Tekla, Dóra Farkas; Tamás, Király; Tamás, Pardy; Toomas, Rang; Galina, Rang (2018). Application of power line communication technology in street lighting control. *International Journal of Design and Nature and Ecodynamics*, 13 (2), 176–186.10.2495/DNE-V13-N2-176-186.

Kaitstud üks doktoritöö: Tamás Pardy (juhendajad prof. Toomas Rang, dr. Indrek Tulp, dotsent Ants Koel). T. Pardy jätkab 2019. aastal järel doktorantuuris Budapesti Tehnoloogia ja Majandusteaduste ülikoolis (juhendaja prof. Marta Rencz, kaasjuhendaja prof. T. Rang).

2018. aastal teostati uurimis- ja arendustööd järgmiste projektide raames:

1. Impedants-spektroskoopia põhine objektide identifitseerimine ja juhtimine: signaalid, algoritmid, energiasäästlikud lahendused (IUT1911, T. Rang);
2. Laia keelutsooniga pooljuhtmaterjalidel põhinevad heterosiirded (PUT1435, A. Koel);
3. Horizon 2020 ERA-Chair Kognitiivne elektroonika - KOEL (VFP15051, A. Kurrel, Y. L. Moullec, M. Alam, T. Rang);
4. ESS/Teekaart infrastruktuuri projekt FPGA (AR17111, A. Koel);
5. ESS/Teekaart infrastruktuuri projekt EtherCAT (VA16039, A. Koel);
6. Tallinna Tehnikaülikooli tudengisatelliidi projekt (A. Koel).

Uute projektide taotlused:

1. COST Action Proposal OC-2018-2-23203 „Lab-on-PCB Bridge“; koordinaator dr. Despina Moschou; Centre for Biosensors, Bioelectronics and Biodevices (C3Bio), Department of Electronic and Electrical Engineering; University of Bath, UK. Tallinna Tehnikaülikooli poolsed koordinaatorid prof. T. Rang ja dr. T. Pardy;
2. COST Action Proposal OC-2018-2-23512 "Pan-European Compact/SPICE Modeling Application Network", koordinaator dr. Jean-Michel Sallese, School of Engineering, EPFL Lausanne, Switzerland. Tallinna Tehnikaülikooli poolsed koordinaatorid prof. T. Rang, dr. J. Mihhailov ja A. Eek;
3. H2020-NMBP-ST-IND-2019 Call: „CONNECT – Increasing Energy Conversion Efficiency in Concentrated Solar Tower plants: Harvesting and Storing Solutions“, koordinaator prof.

Francisco Javier Perez Trujillo, Chemical and Materials Engineering Department, Faculty of Chemical Sciences, Universidad Complutense de Madrid, Spain. Tallinna Tehnikaülikooli pooled koordinaatorid prof. T. Rang ja dr. T. Pardy.

4.

Research Group of Semiconductor Electronics

Head of the research group: Prof. Toomas Rang, toomas.rang@taltech.ee.

Research Group of Semiconductor Electronics belongs to the Research Laboratory for Communicative Electronics.

Keywords: wide bandgap materials' based semiconductor devices, SiC, surface characterization and interfaces, heterojunctions, graphene, lab-on-chip solutions, metallization technologies, diffusion welding, solid state electronics, numerical experiments.

The research group focuses on investigations of SiC based structures. In 2018, modules of vertical architecture based on SiC diodes using diffusion-welding technologies have been completed. Upgrade of the prototype of a voltage doubler using the self-capacitance of SiC diodes was searched. Together with Ioffe institute from St. Petersburg the graphene film behavior on SiC surface topography (multiscale surfaces) for molecular sensorics has been completed and simulation of sensors based on graphene were started. Numerical experiments for investigation of the heterostructures characteristics, properties and the influence of defects were carried out in the frames of PUT1435 and partly IUT1911. Additionally, members of this research group (Dr. Ants Koel, K. Pärnamets, etc.) are responsible for the supervision of the first Taltech student satellite electronics modules development.

The research group has accomplished following scientific results in 2018:

1. Through the numerical experiments the increase the charge carriers scattering phenomena due to the SiC surface defects has been shown, which subsequently decrease the forward current and increases the reverse breakdown voltage of the heterojunctions;
2. The JBS device structure, which is the symbiosis of pn- and Schottky junctions, takes place the faster increase of the total junctions' capacitance, which leads to stronger influence of output voltage on input voltages due to additionally accumulated charge, which must be taken into account in applications of high voltage SiC stacks;
3. On base of results of numerical experiments the dependence of density of states in graphene surfaces in the presence of phenol and methanol molecules has been shown which leads to the change of surface conductivity to be used in graphene sensors applications;
4. Using the comprehensive thermal analysis methodology the verification of assay compliance to LoC NAAT devices has been demonstrated for the heating solution with optimal power efficiency in LoC applications;
5. The new concept of linear modulation application was proofed and the circuitry solution for the 200MHz, programmable gain power combiner with pre-modulation for enhanced linearity using 35nm CMOS technology has been developed and justified.

The research group has accomplished following development results in 2018:

1. Development of prototype for energy management on microchips (J. Mihhailov, M. Koort);
2. Development of Lab-on-Chip prototype for detection of pathogens (T. Pardy and SelfDiagnostics GmBH);
3. Development of pre-production platform of wireless communication microchips (V. Kampus and Intel Austria);

4. The specific hardware solutions for European Spallation Source in Lund, Sweden have been designed, verified and delivered.

International conference BEC2018 was successfully held in Tallinn (A. Koel, F. Rang).

Selected publications:

1. Pardy, Tamás; Rang, Toomas; Tulp, Indrek (2018). Thermal Analysis of a Disposable, Instrument-Free DNA Amplification Lab-on-a-Chip Platform. *Sensors*.10.3390/s18061812;
2. Rashid, M.H.; Koel, A.; Rang, T. (2018). Simulations of heterostructures based on 3C-4H and 6H-4H silicon carbide polytypes. *Materials Science Forum*, 924 MSF, 302–305.10.4028/www.scientific.net/MSF.924.302;
3. Korolkov, Oleg; Land, Raul, Toompuu, Jana; Sleptšuk, Natalja; Rang, Toomas (2018). SiC JBS Diode Symmetrical Voltage Doubler Represented as the Diffusion-Welded Stack. *Materials Science Forum*, 924, 862–865.10.4028/www.scientific.net/MSF.924.862;
4. Rashid, H.; Koel, A.; Rang, T. (2018). Simulations of Propane and Butane Gas Sensor Based on Pristine Armchair Graphene Nanoribbon. *IOP Conference Series: Materials Science and Engineering*, 362: 2018 International Conference on Smart Engineering Materials, ICSEM 2018; Bucharest; Romania; 7 March 2018 through 9 March 2018. Institute of Physics Publishing, (Issue 1).10.1088/1757-899X/362/1/012001;
5. Tekla, Dóra Farkas; Tamás, Király; Tamás, Pardy; Toomas, Rang; Galina, Rang (2018). Application of power line communication technology in street lighting control. *International Journal of Design and Nature and Ecodynamics*, 13 (2), 176–186.10.2495/DNE-V13-N2-176-186.

Tamás Pardy (supervisors Prof. Toomas Rang, Dr. Indrek Tulp, and associate professor Dr. Ants Koel) has successfully defended his PhD thesis. T.Pardy continues his research during 2019 at the Budapest University of Technology and Economics under supervision of Prof. Marta Rencz, co-supervisor Prof. T. Rang from TalTech.

In 2018, the R&D activities were conducted in the frames of the following projects:

1. Impedance spectroscopy based identification and control of objects: signals, algorithms, energy efficient solutions (IUT1911, T. Rang);
2. Heterojunctions based on Wide Bandgap Semiconductor Materials (PUT1435, A. Koel);
3. Horizon 2020 ERA-Chair Cognitive Electronics – COEL (VFP15051, A. Kurrel, Y. L. Moullec, M. Alam, T. Rang);
4. ESS/Teekaart Project for infrastructure FPGA (AR17111, A. Koel);
5. ESS/Teekaart Project for infrastructure EtherCAT (VA16039, A. Koel);
6. Taltech student satellite project (A. Koel).

New project applications:

1. COST Action Proposal OC-2018-2-23203 „Lab-on-PCB Bridge“; project coordinator Dr Despina Moschou; Centre for Biosensors, Bioelectronics and Biodevices (C3Bio), Department of Electronic and Electrical Engineering; University of Bath, UK. TTU coordinators Prof. T. Rang ja Dr. T. Pardy;
2. COST Action Proposal OC-2018-2-23512 "Pan-European Compact/SPICE Modeling Application Network"; project coordinator Dr Jean-Michel Sallese, School of Engineering, EPFL Lausanne, Switzerland. TTU coordinators Prof. T. Rang, Dr. J. Mihhailov and A. Eek;

3. H2020-NMBP-ST-IND-2019 Call: „CONNECT – Increasing Energy Conversion Efficiency in Concentrated Solar Tower plants: Harvesting and Storing Solutions“, project coordinator Prof. Francisco Javier Perez Trujillo, Chemical and Materials Engineering Department, Faculty of Chemical Sciences, Universidad Complutense de Madrid, Spain. TTU coordinators Prof. T. Rang and Dr. T. Pardy.

2.2 Impedants-spektroskoopia teadusgrupp

Uurimisrühma juht: prof. Olev Märtens, olev.martens@taltech.ee.

Impedants-spektroskoopia teadusgrupp kuulub siduselektronika teaduslabori koosseisu.

Märksõnad: impedants-spektroskoopia, impedants-tomograafia, pöörivool, reaal-ajaline, mõõtmine ja mõõteriistad.

Grupp teostab elektrilise impedants-spektroskoopia (EIS) mõõtmislahenduste teadus- ja arendustegevust. See hõlmab vastavate instrumentide, signaalide ja signaalitöötuse arendamist ja uurimist erinevate rakenduste jaoks (mh testiks ja diagnostikaks, nt bio-, tervise- ja meditsiinitehnoloogiates, mikrofluidikas, metalli- ja elektroonikatööstustes ja mujal).

Teadusgrupi peamised uurimistöö tulemused 2018. aastal.

1. Tallinna Tehnikaülikool esitas teadusgrupi koosseisus M.Min (uurimisgrupi juht), O.Märtens, P.Annus, R.Land ja J.Ojarand Eesti Vabariigi teaduspreemia „Teadusala paradigmat ja maailmapilti mõjutava või uut teadusvaldkonda rajava teadusliku avastuse või olulise sotsiaalmajandusliku mõjuga innovaatilise tooteni viinud teaduslikul avastusel põhineva leiutise või teadus- ja arendustöö eest“ kandidaadiks töö „Elektrilise impedantsi mõõtmise paradigma muutmine ning sellel põhineva originaalse tehnoloogia ja aparatuuri väljatöötamine ning rakendamine meditsiinilises ja tehnilises diagnostikas“ eest;
2. IEEE IMS'i auhind "Impedants-spektroskoopia" magistrikursuse arendamiseks (O.Märtens jt.);
3. Raamatu (monograafia) avaldamise leping „Bioimpedance and Spectroscopy“ (P.Annus, M.Min), Elsevier 202;
4. Uurimistöö tulemuste põhjal saadi 2 patenti:
 - a. Eesti patent EE05813 impedantsi mõõtmise vallast (O.Märtens jt.),
 - b. USA patent 10,156,600 (O.Märtens jt.).

Valik olulisemaid artikleid.

1. Kõiv, H.; Rist, M.; Min, M. Development of bioimpedance sensing device for wearable monitoring of the aortic blood pressure curve. *tm - Technisches Messen*, 85 (5).
2. Ojarand, J.; Min, M. (2018). On the selection of excitation signals for the fast spectroscopy of electrical bioimpedance. *Journal of Electrical Bioimpedance*, 9 (1), 133–141.10.2478/joeb-2018-0018.
3. Butsenko, M.; Martens, O.; Krivosei, A.; Le Moullec, Y.. Sparse Reconstruction Method for Separating Cardiac and Respiratory Components from Electrical Bioimpedance Measurements. *Elektronika ir Elektrotehnika*, 24 (5).
4. Gupta, A.; Saar, T.; Märtens, O.; Le Moullec, Y. Automatic Detection of Multisize Pulmonary Nodules in CT Images: Large-Scale Validation of the False-Positive Reduction Step. *Medical Physics*, 45 (3), 1135–1149.

Esimese artikli (H.Kõiv et al.) antud loetelust esitas uurimisgrupp ülikooli 2018. aasta parima teadusartikli konkursile.

Doktoritööd kaitsesid Margus Metshein (juhendaja vanemteadur Paul Annus, kaasjuhendajad prof. Alvo Aabloo, emeritprofessor Mart Min), Marek Rist (juhendaja emeritprofessor Mart Min, kaasjuhendaja dr. Olfa Kanoun), Anindya Gupta (juhendaja prof. Olev Märten, kaasjuhendajad prof. Yannick Le Moullec, dr. Ida-Maria Sintorn), Maksim Butsenko (juhendaja prof. Olev Märten, kaasjuhendaja prof. Yannick Le Moullec).

2018. aastal teostati uurimistööd järgmiste projektide raames:

1. Impedants-spektroskoopia põhine objektide identifitseerimine ja juhtimine: signaalid, algoritmid, energiasäästlikud lahendused (IUT1911, T. Rang);
2. Teaduse Tippkeskus EXCITE (TAR16013IE, M. Kruusmaa);
3. Mõõtetehnoloogiate eeluuring (2. osa). Impedantsspektroskoopia rakendamine suuremahulises autotööstuses (Lep18037, AS Norma/Autoliv, O. Märten);
4. Multiplekseri ning stimuleerimis ja mõõtekanalite kodeerimismatriksi integreerimine olemasoleva Quadra seadmega (VA17133, Tampere Tehnikaülikooli SA, P. Annus, esitatud TalTechi 2018. a tehtud parimate arendustööde konkursile „Impedants-spektrotomograaf QT18“ seadme ja tehnoloogia arendusena);
5. Kantavad robotid inimese mootorsete funktsioonide laiendamiseks, abistamiseks või asendamiseks (VEU17072, M. Min);
6. Energiahoidlikud ja sujuvkantavad sensorseadmed tervishoiu ja elustiili rakendustes (ETAg17090, M. Min, seotud EU FET-projektiga, seotud EU FET-projektiga “HEALTH-EU”, vt all olevat lõiku).

Uute projektide taotlused:

2018. a septembris esitati 2. etapi projektitaotlus „HEALTH-EU” (Euroopa FET-tulevase areneva tehnoloogia, juhtalgatus, M. Min). Otsust ei ole veel tehtud, kuid projekt on valitud 6 finalisti sekka. Loodud on umbes 100 partneriga konsortsium: täispartnerid (teadus) ja toetavad partnerid (ettevõtted, meeskonnad, sealhulgas Siemens, Philips, STM Micro, Bosch, Fraunhofer, Max Planck jt). Konsortsium taotleb 1 miljard eurot 10 aasta jooksul.

Research Group of Impedance Spectroscopy

Head of the research group: Prof. Olev Märten, olev.martens@taltech.ee.

Research Group of Impedance Spectroscopy belongs to the Research Laboratory for Communicative Electronics.

Keywords: impedance spectroscopy, impedance tomography, eddy current, real-time, measurement, instrumentation.

The group performs R&D of electrical impedance spectroscopy (EIS) measurement solutions. This covers the developing and investigation of related instrumentation, signals and signal processing for several applications (including test and diagnostics e.g. in bio-, healthcare, medical and microfluidics areas, for metal-, electronics- and other industries).

The research group has accomplished following results in 2018:

1. TalTech submitted the research team M. Min (head of the team), O. Märtens, P. Annus, R. Land and J. Ojarand as a candidate for the Estonian National research award “For an outstanding scientific discovery – a scientific discovery that changed the paradigm in the relevant area of research, or created a new field of research or led to the creation of an innovative product, which has a significant socio-economic impact” for their work “Shifting the paradigm in electrical impedance measurement and the development of original technology and instrumentation on that bases for medical and technical diagnostics”;
2. IEEE IMS award for development of Master level course called "Impedance Spectroscopy" (O.Märtens, et al);
3. Agreement signed on publication of a book (monography) „Bioimpedance and Spectroscopy“, (P.Annus, M.Min), Elsevier 2020;
4. Based on results of the research, following impedance-measurement related patents were issued to the research group:
 - a. Estonian Patent EE05813 (O.Märtens, et al);
 - b. USA patent 10,156,600 (O.Märtens et al).

Selected publications:

1. Kõiv, H.; Rist, M.; Min, M. Development of bioimpedance sensing device for wearable monitoring of the aortic blood pressure curve. *tm - Technisches Messen*, 85 (5);
2. Ojarand, J.; Min, M. (2018). On the selection of excitation signals for the fast spectroscopy of electrical bioimpedance. *Journal of Electrical Bioimpedance*, 9 (1), 133–141.10.2478/joeb-2018-0018;
3. Butsenko, M.; Martens, O.; Krivosei, A.; Le Moullec, Y.. Sparse Reconstruction Method for Separating Cardiac and Respiratory Components from Electrical Bioimpedance Measurements. *Elektronika ir Elektrotechnika*, 24 (5);
4. Gupta, A.; Saar, T.; Märtens, O.; Le Moullec, Y. Automatic Detection of Multisize Pulmonary Nodules in CT Images: Large-Scale Validation of the False-Positive Reduction Step. *Medical Physics*, 45 (3), 1135–1149.

The paper by H.Kõiv et al from this list was proposed by the research group as the candidate for the best research paper of 2018 of the university.

Several PhD students have successfully defended their theses: Margus Metshein (supervisor Senior Researcher Paul Annus, co-supervisors Prof. Alvo Aabloo, Professor Emeritus Mart Min), Marek Rist (supervisor Professor Emeritus Mart Min, co-supervisor Dr. Olfa Kanoun), Anindya Gupta (supervisor Prof. Olev Märtens, co-supervisors Prof. Yannick Le Moullec, Dr. Ida-Maria Sintorn), Maksim Butsenko (supervisor Prof. Olev Märtens, co-supervisor Prof. Yannick Le Moullec).

In 2018, the research activities were conducted mostly in the frame of the following projects:

1. Impedance spectroscopy based identification and control of objects: signals, algorithms, energy efficient solutions (IUT1911, T. Rang);
2. Estonian Centre of Excellence in ICT Research EXCITE (TAR16013IE, M. Kruusmaa);
3. Preliminary study of measurement techniques (part 2) (Lep18037, Norma AS/Autoliv, applying impedance spectroscopy to a large-scale automotive industry, O.Märtens);
4. Integrating multiplexer and stimulation and measurement coding matrix to existing Quadra device (VA17133, Tampere University Foundation, P.Annus);
5. Wearable Robots for Augmentation, Assistance or Substitution of Human Motor Functions (VEU17072, M.Min);

6. Frictionless Energy Efficient Convergent Wearables For Healthcare and Lifestyle Applications (ETAg17090, M.Min, related EU FET Flagship project, related to the "HEALTH-EU" proposal- see below).

New project applications:

2-nd stage project proposal "HEALTH-EU" (under European FET -Future Emerging Technologies, Flagship initiative) was submitted in September 2018 (M.Min). The decision is not yet made, however, the project has been selected to the 6 finalists. The consortium of around 100 partners has been created: full partners (science) and supporting partners (companies, teams, including Siemens, Philips, STM Micro, Bosch, plus Fraunhofer, Max Planck and others). The consortium is requesting 1 billion Euros for 10 years.

2.3 Kognitiivelektroonika ja traadita side teadusgrupp

Uurimisrühma juht: prof. Muhammad Mahtab Alam, muhammad.alam@taltech.ee.

Kognitiivelektroonika ja traadita side teadusgrupp kuulub kognitroonika teaduslabori koosseisu.

Märksõnad:

- Traadita side: raadiovõrgu ressursside ja interferentsi haldus, madala võimsustarbega sidelahendused tervisetehnoloogiates;
- Kognitiivelektroonika: ligikaudsed arvutused (*approximate computing*), arvutused ebastabiilsetes tingimustes (*transient computing*), energiakorilusele orienteeritud madala energiatarbega IoT platvormid.

Uurimisgrupp arendab välja meetodeid ja tehnikaid piiratud ressursiga arvutus- ja traadita side lahendustele. Uurimisgrupi peamised uurimistöö valdkonnad on: 5G (5. põlvkonna mobiilside), NBloT (*kitsaribaline asjade Internet*), raadiovõrgu ressursside ja interferentsi haldus, keskkonnasõbralik IoT, seadmelt-seadmele sidelahendused, kantavad inimkeha piires levivad raadiovõrgud.

Teadusgrupi peamised uurimistöö tulemused 2018. aastal.

1. Saavutati rahvusvahelise konkurentsi tingimustes üks tenuuri rajal olev professori koht ja atesteerimise läbi ka üks tenuuri professori koht.
2. Edukas PUT taotlus "Closed-loop communication system to support highly responsive neuromuscular assistive stimulation" (M. M. Alam, jt).
3. Projekti EU Horizon 2020 ERA-Chair "Cognitive Electronics COEL" raames mitmete kõrgetasemeliste teadusartiklite publitseerimine, doktoriõppe tulemuslik korraldamine.
4. Koostöös Telia Eesti AS-ga paigaldati NBloT testvõrk Tallinn Tehnikaülikooli linnakusse, viidi läbi raadiovõrgu kontrollmõõtmised ja esitati Teliale võrgu optimeerimiseks vajalikud andmed, mille tulemusena Telia parendas NBloT testvõrgu tööd.
5. Projekti NATO SPS "Public Safety Communication in the Context of Terrorist Attacks" edukas täitmine, sh koostöövõrgustiku loomine ja doktorantide ning järeldoktor-teadurite leidmine.
6. Edukas rahvusvaheline koostöö välisülikoolidega: Politecnico Di Milano (DEIB Instituut) Itaaliast, University of Glasgow (Communication Systems Department) Suurbritanniast, Oulu Ülikool (Center for Wireless Communication) Soomest, National Taipei University of Technology (Electronics) Taivanist, National University of Science and Technology (SEECs) Pakistanist.
7. Panus rahvusvaheliste standardite loomisesse:

- a. IEEE Green ICT standard:
 - IEEE P1923.1/1924.1 töögrupp "Energy-Efficient Communications Hardware (EECH)",
 - koostöö Ex-MIT/Intel kolleegidega,
 - Panasonic/TU-Delf.
- b. ETSI SmartBAN – Low complex BAN and beyond standard:
 - koostöö CWC-Oulu Ülikooliga MAC-kihil,
 - Toshiba juhib ühilduvate seadiste tootmise poolt.

8. Rahvusvaheliste töötubade korraldamine:

- a. töötuba „Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments (RACT-5G-IoT 2019), 08.05.2018, Porto, Portugal konverentsi „9th International Conference on Ambient Systems, Networks and Technologies“ (08-11.05.2018) raames;
- b. Töötuba „Recent Advances in Cellular Technologies and 5G for IoT Environments (RACT-5G-IoT 2019), 29.04.2019, Leuven, Belgia konverentsi „10th International Conference on Ambient Systems, Networks and Technologies“ (29.04-02.05.2018) raames.

Valik olulisemaid artikleid.

1. H. Malik, H. Pervaiz, M. M. Alam, Y. Le Moullec, A. Kuusik and M. Ali Imran, "Radio Resource Management Scheme in NB-IoT Systems," in *IEEE Access*, vol. 6, pp. 15051-15064, 2018.
2. M. M. Alam, H. Malik, M. I. Khan, T. Pardy, A. Kuusik and Y. Le Moullec, "A Survey on the Roles of Communication Technologies in IoT-Based Personalized Healthcare Applications," in *IEEE Access*, vol. 6, pp. 36611-36631, 2018.
3. H. Malik, M. M. Alam, Y. Le Moullec, Q. Ni, "Interference-Aware Radio Resource Allocation for 5G Ultra-Reliable Low-Latency Communication", *IEEE GLOBECOM*, 2018.
4. A. Kuusik, M. M. Alam, T Kask, K Gross-Paju, "Wearable M-Assessment System for Neurological Disease Patients", *IEEE 4th World Forum on Internet of Things*, 2018.
5. S. Ulp, Y. Le Moullec, M- M. Alam, "Energy-Efficient Distributed Leader Selection Algorithm for Energy-Constrained Wireless Sensor Networks", *IEEE Access* vol. 7, pp 4410-4421, 2018.

Doktoritööd kaitsesid Ahti Ainomäe (juhendaja prof. Yannick Le Moullec, kaasjuhendajad prof. Mats Bengtsson, dr. Tõnu Trump), Faisal Ahmed (juhendaja prof. Yannick Le Moullec, kaasjuhendajad vanemteadur Gert Tamberg, vanemteadur Paul Annus); Mohammad Tariq Meeran (kaitses Tallinna Ülikoolis, juhendajad prof. Yannick Le Moullec, kaasjuhendaja vanemteadur Paul Annus).

2018. aastal teostati uurimistööd järgmiste projektide raames:

1. TTÜ Arenguprogramm 2016-2022 (ASTRA 6-2, M. M. Alam, jt);
2. NATO-Science for Peace and Security project Public Safety Communication in the Context of Terrorist Attacks (VNT18039, M. M. Alam);
3. Horizon 2020 ERA-Chair Kognitiivne elektroonika - KOEL (VFP15051, A. Kurrel, Y. L. Moullec, M. Alam, T. Rang).

Hiljuti alanud projektid:

1. Alates 1. jaanuarist 2019, "LUCIA", Interreg Baltic Sea Region, (2018).

Uued projektitaotlused:

1. 14. novembril 2018 esitati "5G SWITCH", H2020, H2020-ICT-2018-3,
2. 15. novembril 2018 esitati "TWINNING4SMARTHEALTH", H2020, WIDESPREAD-03-2018,

3. 31. jaanuaril 2019 esitati: "SUCCESS", EEA-Norway Grants, 2018,
4. SU-DRS02-2019 Technologies for first responders (tähtaeg august 2019),
5. SC1-DTH-02-2020: Personalised early risk prediction, prevention and intervention (tähtaeg ei ole veel fikseeritud).

Research group of Cognitive Electronics and Wireless Communication

Head of the research group: Prof. Muhammad Mahtab Alam, muhammad.alam@taltech.ee

Research group Cognitive Electronics and Wireless Communication belongs to the Research Laboratory for Communicative Electronics.

Keywords:

- Wireless communication: radio resource and interference management, low-power communication technologies for healthcare;
- Cognitive electronics: transient and approximate computing, energy harvesting-driven low power IoT platforms.

The research group members develop methods and techniques for resource-constrained computing and wireless communication. Key research areas: 5G, NB-IOT, radio resource and interference management, green IoT, device-to-device communication, wearable wireless body area networks.

The research group has accomplished following results in 2018:

1. Obtained one tenure-track professorship position (through international competition) and a positive attestation for one tenured professorship;
2. Successful application for PUT "Closed-loop communication system to support highly responsive neuromuscular assistive stimulation" (M. M. Alam, et al);
3. Successful implementation of project EU Horizon 2020 ERA-Chair "Cognitive Electronics COEL": publication of research papers, successful tutoring of PhD students;
4. In cooperation with Telia Eesti AS, NB-IoT test network has been implemented on Tallinn University of Technology campus, coverage measurement campaigns have been carried out and as a result Telia improved the quality of their network;
5. Successful launch of NATO SPS "Public Safety Communication in the Context of Terrorist Attacks" project: establishing of network of contacts, involvement of PhD students and postdoc researchers, etc;
6. Successful international cooperation with Politecnico Di Milano (DEIB Department), Italy; University of Glasgow (Communication Systems Department), UK; Oulu University (Center for Wireless Communication), Finland; National Taipei University of Technology (Electronics), Taiwan; National University of Science and Technology (SEECS), Pakistan;
7. Contributions to standards:
 - a. IEEE Green ICT Standard:
 - IEEE P1923.1/1924.1 Working Group "Energy-Efficient Communications Hardware (EECH)",
 - Cooperation with Ex-MIT/Intel Colleagues,
 - Panasonic/TU-Delf;
 - b. ETSI SmartBAN – low complex BAN and beyond standard:
 - Contributions along with CWC-Oulu University on the MAC layer,
 - Toshiba is main driver for the compliance devices;

8. Organization of International Workshops:
 - a. First Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments (RACT-5G-IoT 2019), May 8, 2018, Porto, Portugal, In conjunction with the 9th International Conference on Ambient Systems, Networks and Technologies, May 8-11, 2018;
 - b. Second Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments (RACT-5G-IoT 2019), April 29, 2019, Leuven, Belgium In conjunction with the 10th International Conference on Ambient Systems, Networks and Technologies, April 29 - May 2, 2019.

Selected publications:

1. H. Malik, H. Pervaiz, M. M. Alam, Y. Le Moullec, A. Kuusik and M. Ali Imran, "Radio Resource Management Scheme in NB-IoT Systems," in *IEEE Access*, vol. 6, pp. 15051-15064, 2018;
2. M. M. Alam, H. Malik, M. I. Khan, T. Pardy, A. Kuusik and Y. Le Moullec, "A Survey on the Roles of Communication Technologies in IoT-Based Personalized Healthcare Applications," in *IEEE Access*, vol. 6, pp. 36611-36631, 2018;
3. H. Malik, M. M. Alam, Y. Le Moullec, Q. Ni, "Interference-Aware Radio Resource Allocation for 5G Ultra-Reliable Low-Latency Communication", *IEEE GLOBECOM*, 2018;
4. A. Kuusik, M. M. Alam, T Kask, K Gross-Paju, "Wearable M-Assessment System for Neurological Disease Patients", *IEEE 4th World Forum on Internet of Things*, 2018;
5. S. Ulp, Y. Le Moullec, M- M. Alam, "Energy-Efficient Distributed Leader Selection Algorithm for Energy-Constrained Wireless Sensor Networks", *IEEE Access* vol. 7, pp 4410-4421, 2018.

Following PhD students have successfully defended their theses: Ahti Ainomäe (supervisor Prof. Yannick Le Moullec, co-supervisors Prof. Mats Bengtsson, Dr. Tõnu Trump), Faisal Ahmed (supervisor Prof. Yannick Le Moullec, co-supervisors Senior Researcher Gert Tamberg, Senior Researcher Paul Annus); Mohammad Tariq Meeran (defended at Tallinn University, supervisor prof. Yannick Le Moullec, co-supervisor Senior Researcher Paul Annus).

In 2018, the research activities were conducted in the frames of following projects:

1. TTÜ Development Program 2016-2022 (ASTRA-6-2, M. M. Alam, et al);
2. NATO-Science for Peace and Security project Public Safety Communication in the Context of Terrorist Attacks (VNT18039, M. M. Alam);
3. Horizon 2020 ERA-Chair project Cognitive Electronics – COEL (VFP15051, A. Kurrel, Y. L. Moullec, M. Alam, T. Rang).

Recently started project:

1. Started on 1 January 2019, "LUCIA", Interreg Baltic Sea Region, third call (2018).

New project applications:

1. Submitted on 14 November 2018: "5G SWITCH", H2020, H2020-ICT-2018-3 call,
2. Submitted on 15 November 2018: "TWINNING4SMARTHEALTH", H2020, WIDESPREAD-03-2018 call,
3. To be submitted on 31 January 2019: "SUCCESS", EEA-Norway Grants, 2018 call,
4. SU-DRS02-2019 Technologies for first responders (Deadline August 2019),
5. SC1-DTH-02-2020: Personalised early risk prediction, prevention and intervention (call not confirmed yet).