

Thomas Johann Seebecki elektroonikainstituudi 2020. aasta teadus- ja arendustegevuse aruanne

1. Struktuuriüksuse struktuur 2020. 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 ja uurimisrühmad on:

- elektroonika ja sidetehnika õppekeskus, õppekeskuse juht Andres Eek, andres.eek@taltech.ee;
- kognitronika teaduslabor, labori ja uurimisrühma juht prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee;
- mõõteelektronika uurimisrühm, uurimisrühma juht prof. Olev Märten, olev.martens@taltech.ee;
- kommunikatsioonisüsteemide uurimisrühm, uurimisrühma juht prof. Muhammad Mahtab Alam, muhammad.alam@taltech.ee.

Units and research groups inside of the department are:

- Study Center for Electronics and Communicative Technologies, head of the study center Andres Eek, andres.eek@taltech.ee;
- Research Laboratory for Cognitronics, head of the laboratory and research group Prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee;
- Measurement Electronics Research Group, head of the research group Prof. Olev Märten, olev.martens@taltech.ee;
- Communication Systems Research Group, head of the research group Prof. Muhammad Mahtab Alam, muhammad.alam@taltech.ee.

2. Teadus- ja arendustegevuse ülevaade uurimisrühmade lõikes

2.1 Thomas Johann Seebecki elektroonikainstituudi mõõteelektronika uurimisrühm

Uurimisrühma juht: Prof. Olev Märten, olev.martens@taltech.ee, tel. 620 2167

Uurimisrühma liikmed:

Paul Annus, vanemteadur
Mart Min, teadur, emeriitprofessor
Jaan Ojarand, vanemteadur
Andrei Krivošei, vanemteadur
Raul Land, vanemteadur
Marek Rist, teadur
Margus Metshein, teadur
Hip Kõiv, doktorant, insener
Ksenija Pesti, doktorant
Eiko Priidel, doktorant-nooremteadur
Robin Benjamin Ehrminger, doktorant

VÕTMESÕNAD: impedants-spektroskoopia, impedants-tomograafia, pöörisvool, real-aja, mõõtmine, mõõteriistad.

Uurimisrühma teadus- ja arendustegevus on suunatud elektrilise, peamiselt impedants-spektroskoopia (kuid mitte ainult) mõõtmislahendustele. See hõlmab vastavate instrumentide, signaalide ja signaalitötluse arendamist ja uurimist erinevate rakenduste jaoks (mh testiks ja diagnostikaks, nt bio-, tervise- ja meditsiinitehnoloogiates, mikrofluidikas, metalli- ja elektroonikatööstustes ja mujal).

Uurimisrühma peamised tulemused 2020. aastal:

- Konverentsi "IEEE I2MTC 2020 International Instrumentation & Measurement Technology Conference" **parima publikatsiooni auhind:**
Metshein, M.; Annus, P.; Land, R.; Rist, M.; Min, M.; Märten, O. (2020). Correlation between electrical bioimpedance and pressure waveform in radial artery and in mechanical pulsating pipe system. Proceedings of the IEEE Instrumentation and Measurement Technology Conference (I2MTC2020): 2020 IEEE International Instrumentation & Measurement Technology Conference (I2MTC2020), 2020, Dubrovnik, Croatia, 25–28 May. Dubrovnik, Croatia: IEEE Operations Center, 1–6.
- Uurimistöö tulemusena saadi kaks impedantsimõõtmistega seotud **patenti** ning esitati mitu patenditaotlust:
 - R.Land et al, "Method and device for broadband analysis of systems and substances", US10698023 (patent väljastati 30.06.2020);
 - J.Ojarand et al, "Microfluidic method and device", EE201900007 (patent väljastati 15.12.2020);
 - J.Ojarand et al, "Microfluidic method and device", US202025681 (applied)
- Valitud publikatsioonid:
 - Ehrminger, R.; Kopanchuk, S.; Kivirand, K.; Romann, T.; Rinken, T.; Min, M.; Rinken, A. (2020). Characterizing the biofunctionalization of gold surface with total internal

reflection fluorescence (TIRF) microscopy. Proceedings of the Estonian Academy of Sciences, 69 (1), 27–34. DOI: 10.3176/proc.2020.1.02.

- Priidel, E.; Annus, P.; Krivošei, A.; Rist, M.; Land, R.; Min, M.; Märten, O. (2020). Methods for detection of bioimpedance variations in resource constrained environments. Sensors, 20 (5). DOI: 10.3390/s20051363.

Uurimisrühma seotus TalTechi AAK prioriteetse suunaga:

- Targad ja energiatõhusad keskkonnad;
- Tulevikku vaatav riigivalitsemine.

Uurimisrühma tegevusega seotud teadusvaldkond:

2. Tehnika ja tehnoloogia ->2.2 Elektrotehnika, Elektroonika, infotehnika

Olulisemad projektid:

- MOBERA20 "Sündmustepõhine tehisintellekti riistvara biomeditsiini sensoritele (1.12.2019–31.10.2022)", Olev Märten.
- EAG34 "Aordi tsentraalse vererõhukõvera mitteinvasiivne mõõtesensor (1.01.2020–31.12.2020)", Mart Min.

Info uurimisrühma rakendusliku väljundiga teadus- ja arendustegevuse kohta:

- LEP19100 teadus- ja arendustöö leping ettevõttega Huawei Corporation, kantavate seadmete arendamine heaolu tagamiseks.

2.2 Measurement Electronics Research Group of Thomas Johann Seebeck Department of Electronics

Head of the research group: Prof. Olev Märten, olev.martens@taltech.ee, tel. 620 2167

Members of the research group:

Paul Annus, sen. researcher

Mart Min, researcher, prof. emeritus

Jaan Ojarand, sen. researcher

Andrei Krivošei, sen.researcher

Raul Land, sen. researcher

Marek Rist, researcher

Margus Metshein, researcher

Hip Kõiv, doctoral student, engineer

Ksenija Pesti, doctoral student

Eiko Priidel, doctoral student, early stage researcher

Robin Benjamin Ehrminger, doctoral student

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

The group performs R&D of electrical mostly (but not limited) impedance spectroscopy 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 the following results in 2020:

- IEEE I2MTC 2020 International Instrumentation & Measurement Technology Conference **Best Paper Award** for: Metshein, M.; Annus, P.; Land, R.; Rist, M.; Min, M.; Märtens, O. (2020). Correlation between electrical bioimpedance and pressure waveform in radial artery and in mechanical pulsating pipe system. Proceedings of the IEEE Instrumentation and Measurement Technology Conference (I2MTC2020): 2020 IEEE International Instrumentation & Measurement Technology Conference (I2MTC2020), 2020, Dubrovnik, Croatia, 25–28 May. Dubrovnik, Croatia: IEEE Operations Center, 1–6.
- Based on the results of the research, two impedance-measurement related **patents** were granted and several applications were submitted :
 - R.Land et al, "Method and device for broadband analysis of systems and substances", US10698023 (granted 30.06.2020);
 - J.Ojarand et al, "Microfluidic method and device", EE201900007 (granted 15.12.2020);
 - J.Ojarand et al, "Microfluidic method and device", US202025681 (applied)
- Selected publications:
 - Ehrminger, R.; Kopanchuk, S.; Kivirand, K.; Romann, T.; Rincken, T.; Min, M.; Rincken, A. (2020). Characterizing the biofunctionalization of gold surface with total internal reflection fluorescence (TIRF) microscopy. Proceedings of the Estonian Academy of Sciences, 69 (1), 27–34. DOI: 10.3176/proc.2020.1.02.
 - Priidel, E.; Annus, P.; Krivošei, A.; Rist, M.; Land, R.; Min, M.; Märtens, O. (2020). Methods for detection of bioimpedance variations in resource constrained environments. Sensors, 20 (5). DOI: 10.3390/s20051363.

Affiliation of the research team to the TalTech Academic Development Plan priority areas:

- Smart and energy efficient environments;
- Future governance.

Field of research activity of the research group - up to two sub-fields based on the Frascati Manual's classification of scientific fields and disciplines:

- 2. Engineering and technology ->2.2 Electrical engineering, electronic engineering, information engineering

Major research projects:

- MOBERA20 "Chist-ERA Project: JEDAI Event Driven Artificial Intelligence Hardware for Biomedical Sensors" (1.12.2019 -30.10.2022)", Olev Märtens.
- EAG34 "Non-invasive sensor of central aortic blood pressure waveform (2020–2020)", Mart Min.

Information on applied research and development activities of the research group:

- LEP19100 Research and Development Agreement with Huawei Corporation regarding development of wearable device for well-being.

2.3 Thomas Johann Seebecki elektroonikainstituudi kognitroonika teaduslabor

Uurimisrühma juht: Prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee, tel. 5844 6540

Uurimisrühma liikmed:

Muhammad Mahtab Alam, professor
Ants Koel, dotsent
Toomas Rang¹, emeriitprofessor
Tamas Pardy¹, vanemteadur
Kaiser Pärnamets, lektor, doktorant
Sikandar Muhammad Zulqarnain Khan, doktorant
Rauno Jõemaa, doktorant
Udayan Sunil Patankar, doktorant
Haroon Rashid, doktorant
Mehadi Hasan Ziko, doktorant
Fariha Afrin, doktorant-nooremteadur
Kanwal Ashraf, doktorant
Abdul Mujeeb, doktorant-nooremteadur

KEYWORDS: energiatõhusad asjade internet platvormid, kiiplabor; pooljuhtelektroonika, nutikad multiskalaarsed pinnad.

Uurimisrühm arendab:

- mikro- ja sensortehnoloogiaid;
- madala võimsustarbega traadita side tehnoloogiaid;
- kognitiivseid meetodeid sensorandmete töötlemiseks ja tehisintellekti kasutamiseks.

Uurimisrühma peamised tulemused 2020. aastal:

- Läbiviidud üritused:
 - Sümpoosion “Low Power Wide Area Networks Technologies for Internet of Things Symposium”,
 - Balti elektroonikakonverents (BEC) 2020,
 - Konverents “EAI BodyNets 2020”.
- Valitud publikatsioonid (3):
 - Rashid, H. M.; Koel, A.; Rang, T.; Ziko, M. H. (2020). Simulation of Benzene and Hydrogen-Sulfide Gas Detector based on Single-Walled Carbon Nanotube over Intrinsic 4H-SiC Substrate. *Micromachines*, 11, 453–465.
 - Saboor, A.; Ahmad, R.; Ahmed, W.; Kiani, A. K.; Alam, M. M.; Kuusik, A.; Le Moullec, Y. (2020). Dynamic Slot Allocation using Non Overlapping Backoff Algorithm in IEEE 802.15.6 WBAN. *IEEE Sensors Journal*, 10862–10875.
 - Khan, S. Z.; Kakar, R.; Alam, M. M.; Le Moullec, Y.; Pervaiz, H. (2020). A Green IoT Node incorporating Transient Computing, Approximate Computing and Energy/Data Prediction. *Proceedings of IEEE Consumer Communications & Networking Conference 2020 (CCNC 2020)*.

¹ Kuni 2020.a. augusti lõpuni

Uurimisrühma seotus TalTechi AAK prioriteetse suunaga:

- Targad ja energiatõhusad keskkonnad.

Uurimisrühma tegevusega seotud teadusvaldkond:

- 2.2 Elektrotehnika, Elektroonika, infotehnika
- 2.10 Nanotehnoloogia

Olulisemad projektid:

- PUT1435 "Laia keelutsooniga pooljuhtmaterjalidel põhinevad heterosiirded" (18.01.2017-31.12.2020).
- Interreg BSR "LUCIA: Läänemere piirkonna valgustus" (01.01.2019 – 30.06.2021).
- PRG620 "CogniFlow-Cyte: Kognitiivne kiiplaborsüsteem automatiseeritud voolutsütomeetria tarbeks (1.01.2020–31.12.2024)" [Koostöö keemia ja biotehnoloogia instituudiga].

2.4 Research Laboratory for Cognitronics of Thomas Johann Seebeck Department of Electronics

Head of the research group: Prof. Yannick Le Moullec, yannick.lemoullec@taltech.ee, tel. 5844 6540

Members of the research group:

Muhammad Mahtab Alam, prof.
Ants Koel, associate prof.
Toomas Rang², Prof. Emeritus
Tamas Pardy², Senior Researcher
Kaiser Pärnamets, lecturer, PhD student
Sikandar Muhammad Zulqarnain Khan, PhD student
Rauno Jõemaa, PhD student
Udayan Sunil Patankar, PhD student
Haroon Rashid, PhD student
Mehadi Hasan Ziko, PhD student
Fariha Afrin, early stage researcher, PhD student
Kanwal Ashraf, PhD student
Abdul Mujeeb, early stage researcher, PhD student

KEYWORDS: energy-efficient IoT platforms, Lab-on-Chip; semiconductor electronics, smart multiscale surfaces.

The research group develops:

- methods and techniques for miniaturized actuators and sensor technologies;
- resource-constrained implementation of wireless technologies;
- transition methods for exploitation and implementation of sensors in data processing and artificial intelligence for decision-making and actuation.

² Till end of August 2020

The research group has accomplished the following results in 2020:

- Three events were held:
 - Low Power Wide Area Networks Technologies for Internet of Things Symposium,
 - Baltic Electronics Conference (BEC) 2020,
 - EAI BodyNets 2020.

- Selected publications (3):
 - Rashid, H. M.; Koel, A.; Rang, T.; Ziko, M. H. (2020). Simulation of Benzene and Hydrogen-Sulfide Gas Detector based on Single-Walled Carbon Nanotube over Intrinsic 4H-SiC Substrate. *Micromachines*, 11, 453–465.
 - Saboor, A.; Ahmad, R.; Ahmed, W.; Kiani, A. K.; Alam, M. M.; Kuusik, A.; Le Moullec, Y. (2020). Dynamic Slot Allocation using Non Overlapping Backoff Algorithm in IEEE 802.15.6 WBAN. *IEEE Sensors Journal*, 10862–10875.
 - Khan, S. Z.; Kakar, R.; Alam, M. M.; Le Moullec, Y.; Pervaiz, H. (2020). A Green IoT Node incorporating Transient Computing, Approximate Computing and Energy/Data Prediction. *Proceedings of IEEE Consumer Communications & Networking Conference 2020 (CCNC 2020)*.

Affiliation of the research team to the TalTech Academic Development Plan priority areas:

- Smart and energy efficient environments.

Field of research activity of the research group - up to two sub-fields based on the Frascati Manual's classification of scientific fields and disciplines:

- 2.2 Electrical engineering, electronic engineering, information engineering
- 2.10 Nano-technology

Major research projects:

- PUT1435 “Heterojunctions based on Wide Bandgap Semiconductor Materials” (18.01.2017-31.12.2020).
- Interreg BSR "LUCIA: Lighting the Baltic Sea Region" (01.01.2019 – 30.06.2021).
- PRG620 “CogniFlow-Cyte: Cognitronic Lab-on-a-Chip System for Highly-Automated Flow Cytometry” (01.01.2020 - 31.12.2024) [Collaboration with Dept. Chemistry and Biotechnology].

2.5 Thomas Johann Seebecki elektroonikainstituudi kommunikatsioonisüsteemide uurimisrühm

Uurimisrühma juht: Prof. Muhammad Mahtab Alam, muhammad.alam@taltech.ee, tel. 620 2164

Uurimisrühma liikmed:

Toomas Ruuben, professor
Alar Kuusik, vanemteadur
Julia Berdnikova, teadur
Ivo Mürsepp, vanemlektor
Eerik Lossmann, vanemlektor
Priit Roosipuu, sidelahenduste arendaja
Osama Mohamed Mostafa Elgarhy, järel doktor-teadur
Dadmehr Rahbari, järel doktor-teadur
Ali Masood, doktorant
Rida Khan, doktorant
Collins Burton Mwakwata, doktorant
Taavi Laadung, tööstusdoktorant
Marika Kulmar, doktorant-nooremteadur
Harish Kumar Singh, doktorant-nooremteadur

VÕTMESÕNAD: raadiovõrgu ressursside ja interferentsi haldus, masin-masin kommunikatsioon, madala võimsustarbega kommunikatsioonitehnoloogiad tervishoius, 5G (5. põlvkonna) ja 5G-järgne mobiilsid, NB-IoT (kitsaribaline asjade Internet), BAN.

Uurimisrühma teadus- ja arendustegevus on suunatud raadiovõrgu interferentsi haldamisele traadita sides: tehnikad ja algoritmid 5G raadioside võimaldamiseks; 5G testikeskkonna arendamine, mh suure arvu masinate vahelise lairiba-mobiilsid teenused ja kõrge usaldusväärsuse ja lühikese latentsusajaga sideteenused ning digiühiskonna (tark tervishoid, tark linn, tööstus 4.0) vertikaalsete teenuste arendamine, sh ühenduvus, mobiilsus, lõppkasutajad.

Uurimisrühma peamised tulemused 2020. aastal.

- Panus rahvusvaheliste standardite arendamisse:
 - ETSI SmartBAN TR 103 711 "Tööartikli pealkiri: Smart Body Area Network (SmartBAN); Applying SmartBAN MAC (ETSI TS 103 325) for various use-cases".
- Valitud publikatsioonid:
 - H. Malik, M. M. Alam, H. Pervaiz, Y. Le Moullec, A. Al-Dulaimi, S. Päränd, L. Reggiani, "Radio Resource Management in NB-IoT Systems: Empowered by Interference Prediction and Flexible Duplexing," in IEEE Network, vol. 34, no. 1, pp. 144-151, January/February 2020.
 - R. Khan, M. M. Alam, M. Guizani, "A Flexible Enhanced Throughput and Reduced Overhead (FETRO) MAC Protocol for ETSI SmartBAN", IEEE Transactions on Mobile Computing, doi: 10.1109/TMC.2020.3047596.

Uurimisrühma seotus TalTechi AAK prioriteetse suunaga:

- Targad keskkonnad (asjade internet, 5G-asjade internet, targad elektroonsed süsteemid);
- Ühiskonna digitaliseerimine (tervishoiutehnoloogiad).

Uurimisrühma tegevusega seotud teadusvaldkond:

- 2.2 Elektrotehnika, Elektroonika, infotehnika.

Olulisemad projektid:

- VFP20045 H2020 5G-ROUTES: 5th Generation connected and automated mobility cross-border EU trials (2020-2023).
- VNT18039 NATO SPS Public Safety Communication in the Context of Terrorists Attacks (01.06.2018-01.05.2021).
- PRG424 "Tagasisidestatav andmevahetussüsteem kõrge reaktiivsusega abistava neuromuskulaarse stimulatsiooni võimaldamiseks (1.01.2019–31.12.2023)".

Info uurimisrühma rakendusliku väljundiga teadus- ja arendustegevuse kohta:

- LIEEE20118 – Majandus- ja Kommunikatsiooniministeeriumi poolt tellitud rakendusuuring koostöös ettevõttega Civitta Eesti AS 5G teenuste kasutuslugude kohta.
- LEP19033 – rakendusuuring ettevõttega Domotics OÜ „NSP203 - Kiuto hooneautomaatika süsteemi probleemsete komponentide rakendusuuring ja tootearendus “ (rahastus: NUTIKAS meede).

2.6 Communication Systems Research Group of Thomas Johann Seebeck Department of Electronics

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

tel. 620 2164

Members of the research group:

Toomas Ruuben, professor
Alar Kuusik, sen. researcher
Julia Berdnikova, researcher
Ivo Mürsepp, sen. lecturer
Eerik Lossmann, sen. lecturer
Priit Roosipuu, telecom solutions developer
Osama Mohamed Mostafa Elgarhy, post-doctoral researcher
Dadmehr Rahbari, post-doctoral researcher
Ali Masood, doctoral student
Rida Khan, doctoral student
Collins Burton Mwakwata, doctoral student
Taavi Laadung, doctoral student (industrial PhD)
Marika Kulmar, early stage researcher, doctoral student
Harish Kumar Singh, early stage researcher, doctoral student

KEYWORDS: radio resource and interference management, device to device communications, low-power communication technologies for healthcare, 5G and Beyond, NB-IoT, BAN;

The group performs R&D of interference control in wireless communication: techniques and algorithms for enabling 5G new radio, but also development of 5G testbed including support to realize massive machine type communication enhanced mobile broadband services and ultra-reliable and low latency communication services and digitalization of society (i.e., smart healthcare, smart city, industrial automation 4.0) development of vertical applications and services including connectivity, mobility, end-user community.

The research group has accomplished the following results in 2020:

- Contributions in International Standards:
 - ETSI SmartBAN TR 103 711 “Work Item Title: Smart Body Area Network (SmartBAN); Applying SmartBAN MAC (ETSI TS 103 325) for various use-cases”
- Selected publications:
 - H. Malik, M. M. Alam, H. Pervaiz, Y. Le Moullec, A. Al-Dulaimi, S. Päränd, L. Reggiani, "Radio Resource Management in NB-IoT Systems: Empowered by Interference Prediction and Flexible Duplexing," in IEEE Network, vol. 34, no. 1, pp. 144-151, January/February 2020.
 - R. Khan, M. M. Alam, M. Guizani, “A Flexible Enhanced Throughput and Reduced Overhead (FETRO) MAC Protocol for ETSI SmartBAN”, in IEEE Transactions on Mobile Computing, doi: 10.1109/TMC.2020.3047596.

Affiliation of the research team to the TalTech Academic Development Plan priority areas:

- Smart environments (IoT, 5G-IoT, Smart Electronic Systems);
- Digital transformation of the society (Health technologies).

Field of research activity of the research group - up to two sub-fields based on the Frascati Manual's classification of scientific fields and disciplines:

- 2.2 Electrical Engineering, electronics engineering, information engineering

Major research projects:

- VFP20045 H2020 5G-ROUTES: 5th Generation connected and automated mobility cross-border EU trials (2020-2023).
- VNT18039 NATO SPS Public Safety Communication in the Context of Terrorists Attacks (01.06.2018-01.05.2021).
- PRG424 ETAg Closed-loop communication system to support highly responsive neuromuscular assistive stimulation (01.01.2019-31.12.2023).

Information on applied research and development activities of the research group:

- LIEEE20118 Applied Research Agreement with Civitta Eesti AS for 5G services use case study ordered by the Ministry of Economic Affairs and Communications.
- LEP19033 Applied Research Agreement with Domotics OÜ for enhancement of Kiuto smart building system's problematic components (project financed by Archimedes SA with NUTIKAs measure)