

Thomas Johann Seebecki elektroonikainstituudi 2019. aasta teadus- ja arendustegevuse aruanne

Thomas Johann Seebecki elektroonikainstituut (edaspidi TJS [elektroonikainstituut](#)).

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

Direktor Laur Lemendik, 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.

Teadus- ja arendustegevuse ülevaade uurimisrühmade lõikes

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-nooremteadur

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 signaalitöötlemise arendamist ja uurimist erinevate rakenduste jaoks (mh testiks ja diagnostikaks, nt bio-, tervise- ja meditsiinitehnoloogiates, mikrofluidikas, metalli- ja elektroonikatööstustes ja mujal).

Uurimisrühma peamised tulemused 2019. aastal:

- III-IV koht 2019. aasta veebruaris TalTechi 2018. aasta arendustööde konkursil auhinnatud arendusprojekti "*Impedance-spectro tomograph QT18*" eest, uurimismeeskonnas Paul Annus, Mart Min, Olev Märten, Marek Rist, Raul Land;
- Uurimistöö tulemuste põhjal esitati kaks impedantsi mõõtmistega seotud patenditaotlust Eesti Patendiametile:
 - *Method and device for measuring complex transfer of an object*; Omanikud: Tallinna Tehnikaülikool; Autorid: Paul Annus, Raul Land, Mart Min, Olev Märten, Marek Rist, Eiko Priidel; prioriteedi number: P201900031; prioriteedi kuupäev: 19.12.2019.
 - *Microfluidic method and device*; Omanikud: Tallinna Tehnikaülikool; Autorid: Jaan Ojarand, Mart Min, Olev Märten; prioriteedi number: P201900007; prioriteedi kuupäev: 8.02.2019.
- Valitud publikatsioonid:
 - Naranjo-Hernandez, D; Reina-Tosina, J; Min, M. *Fundamentals, Recent Advances, and Future Challenges in Bioimpedance Devices for Healthcare Applications. J. of Sensors, 2019*
 - Ojarand, Jaan; Min, Mart; Koel, Ants (2019). *Multichannel Electrical Impedance Spectroscopy Analyzer with Microfluidic Sensors. Sensors, 19(8)*
 - Gupta, A.; Saar, T.; Martens, O.; Le Moullec, Y.; Sintorn, I-M. *Detection of Pulmonary Micronodules in Computed Tomography Images and False Positive Reduction Using 3D Convolutional Neural Networks. Intern. Journ. of Imaging Systems and Technology, 1–13.*

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:

- IUT19-11 " Impedants-spektroskoopia põhine objektide identifitseerimine ja juhtimine: signaalid, algoritmid, energiasäästlikud lahendused" (1.01.2014–31.12.2019)"
- LEP18037 "Möötetehnoloogiate eeluuring (2. osa), (1.03.2018–20.05.2021)"
- MOBERA20 "Chist-ERA Project: JEDAI Event Driven Artificial Intelligence Hardware for Biomedical Sensors" (1.12.2019 -30.10.2022)

Info uurimisrühma rakendusliku väljundiga teadus- ja arendustegevuse kohta:

- LEP19100 TA leping ettevõttega Huawei Corporation, kantavate seadmete arendamine heaolu tagamiseks.

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, early stage researcher

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

The group performs R&D of electrical (but not limited) impedance spectroscopy measurement solutions. This covers the research and development 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 2019:

- 2019 February awarded: TalTech's Best R&D Project of 2018 Award competition, III-IV place for development project "Impedance-spectro tomograph QT18", research team [Paul Annus](#), Mart Min, Olev Märten, Marek Rist, Raul Land;

- Based on the results of the research, two impedance-measurement related patents applications were submitted to Estonian Patent Office:
 - Method and device for measuring complex transfer of an object; Owners: Tallinna Tehnikaülikool; Authors: Paul Annus, Raul Land, Mart Min, Olev Märtens, Marek Rist, Eiko Priidel; Priority number: P201900031; Priority date: 19.12.2019.
 - Microfluidic method and device ; Owners: Tallinna Tehnikaülikool; Authors: Jaan Ojarand, Mart Min, Olev Märtens; Priority number: P201900007; Priority date: 8.02.2019.
- Selected publications:
 - 2019: Naranjo-Hernandez, D; Reina-Tosina, J; Min, M.. Fundamentals, Recent Advances, and Future Challenges in Bioimpedance Devices for Healthcare Applications. J. of Sensors, 2019
 - 2019: Ojarand, Jaan; Min, Mart; Koel, Ants (2019). Multichannel Electrical Impedance Spectroscopy Analyzer with Microfluidic Sensors. Sensors, 19(8)
 - 2019: Gupta, A.; Saar, T.; Martens, O.; Le Moullec, Y.; Sintorn, I-M. Detection of Pulmonary Micronodules in Computed Tomography Images and False Positive Reduction Using 3D Convolutional Neural Networks. Intern. Journ. of Imaging Systems and Technology, 1–13.

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:

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

Major research projects:

- IUT19-11 "Impedance spectroscopy based identification and control of objects: signals, algorithms, energy efficient solutions (1.01.2014–31.12.2019)"
- LEP18037 "Preliminary study of measurement techniques (part 2), (1.03.2018–20.05.2021)"
- MOBERA20 "Chist-ERA Project: JEDAI Event Driven Artificial Intelligence Hardware for Biomedical Sensors" (1.12.2019 -30.10.2022)

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.

Thomas Johann Seebecki elektroonikainstituudi kognitroonika teaduslabor

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

Uurimisrühma liikmed:

Toomas Rang, professor
Muhammad Mahtab Alam, professor
Ants Koel, dotsent
Oleg Korolkov, vanemteadur
Natalja Sleptšuk, vanemteadur
Jana Toompuu, vanemteadur
Tamas Pardy, teadur
Hassan Malik, teadur
Massimo Leonardo Filograno, järel doktor-teadur
Kaiser Pärnamets, lektor, doktorant
Sikandar Muhammad Zulqarnain Khan, doktorant
Rauno Jõemaa, doktorant
Udayan Sunil Patankar, doktorant-nooremteadur
Haroon Rashid, doktorant-nooremteadur
Mehadi Hasan Ziko, doktorant-nooremteadur

VÕTMESÕNAD: juhu- ja lähendarvutus, energia kogumisele orienteeritud madala võimsustarbega asjade interneti platvormid, kiiplabor, pooljuhtelektroonika, nutikad multiskalaarsed pinnad.

Uurimisrühm arendab mikro- ja sensortehnoloogiaid, madala võimsustarbega traadita side tehnoloogiaid, kognitiivseid meetodeid sensorandmete töötlemiseks ja tehisintellekti (nt masinõpe) kasutamiseks.

Uurimisrühma peamised tulemused 2019. aastal:

- Edukas doktoritöö kaitsmine:
 - Sander Ulp, "Õppimisalgoritmid hajutatud võrkude tarbeks – juhtsõlme hajus valimine", juhendajad prof. Alam ja prof. Moullec;
- ETAgri rühmagrant PRG620 "CogniFlow-Cyte: Kognitiivne kiiplaborsüsteem automatiseeritud voolutsütomeetria tarbeks" (vastutav täitja prof. Rang), kõrgeim hinne insenerivaldkonnas.
- Viidi läbi:
 - Rahvusvaheline töötuba: 29 April - 2 May 2019, Leuven, Belgia: *Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments* (RACT-5G-IoT 2019);
 - Hackathon: 8-10 November 2019, Tallinn: *Hackathon on Cognitive Electronics for Smart Environments*.
- Valitud publikatsioonid:
 - Pardy, T.; Sink, H.; Koel, A.; Rang, T. (2019). *Development of a Low-Cost, Wireless Smart Thermostat for Isothermal DNA Amplification in Lab-On-A-Chip Devices. Micromachines*, 10 (7), 437;
 - Rashid, M. H.; Koel, A.; Rang, T. (2019). *First Principles Simulations of Phenol and Methanol Detector Based on Pristine Graphene Nanosheet and Armchair Graphene Nanoribbons. Sensors*, 19 (12), 2731;
 - Korolkov, O. M.; Kozlovski, V. V.; Lebedev, A. A.; Sleptšuk, N.; Toompuu, J.; Rang, T. (2019). *Low-Temperature Annealing of Lightly Doped n-4H-SiC Layers after Irradiation with Fast Electrons. Semiconductors*, 53 (7), 975–978;

- Khan, S. Z.; Malik, H.; Sarmiento, J. L. R.; Alam, M. M.; Le Moullec, Y. (2019). *DORM: Narrowband IoT Development Platform and Indoor Deployment Coverage Analysis. Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments 2019 (RACT-5G-IoT 2019)*.

Uurimisrühma seotus TalTechi AAK prioriteetse suunaga:

- Targad ja energiatõhusad keskkonnad.

Uurimisrühma tegevusega seotud teadusvaldkond:

- 2.2 Elektrotehnika, Elektroonika, infotehnika
- 2.10 Nanotehnoloogia

Olulisemad projektid:

- VFP15051 H2020 ERA-Chair “Kognitiivne elektroonika” (01.12.2015 – 30.11.2019).
- IUT19-11 " Impedants-spektroskoopia põhine objektide identifitseerimine ja juhtimine: signaalid, algoritmid, energiasäästlikud lahendused (1.01.2014–31.12.2019)"
- PUT1435 “ Laia keelutsooniga pooljuhtmaterjalidel põhinevad heterosiirded” (18.01.2017-31.12.2020)
- Interreg BSR "LUCIA: Läänemere piirkonna valgustus ” (01.01.2019 – 30.06.2021)

Info uurimisrühma rakendusliku väljundiga teadus- ja arendustegevuse kohta:

- Koostöö firmaga SelfDiagnostics: uurimisrühma poolt demonsteeritud temperatuurikontrolli meetodit rakendati SelfDiagnosticsi „Point-of-Care“ testseadmehel, pilootuuring digitaalseks tuvastamiseks ja testitulemuste juhtmevabaks edastamiseks edasiseks analüüsimiseks.
- VA16039 Euroopa Neutronkiirguse Allikale (ESS) disainiti ja toodeti Ethercati moodulite ja FPGA-IoC prototüüpide partiid.

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:

Toomas Rang, professor

Muhammad Mahtab Alam, professor

Ants Koel, associate professor

Oleg Korolkov, sen. researcher

Natalja Sleptšuk, sen. researcher

Jana Toompuu, sen. researcher

Tamas Pardy, researcher

Hassan Malik, researcher

Massimo Leonardo Filograno, post-doc researcher

Kaiser Pärnamets, lecturer, doctoral student

Sikandar Muhammad Zulqarnain Khan, doctoral student

Rauno Jõemaa, doctoral student

Udayan Sunil Patankar, early stage researcher, doctoral student

Haroon Rashid, early stage researcher, doctoral student

Mehadi Hasan Ziko, early stage researcher, doctoral student

KEYWORDS: transient and approximate computing, energy harvesting-driven low power 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 connectivity technologies; transition methods for exploitation and implementation of sensors in data processing and artificial intelligence (e.g. machine learning) for decision-making and actuation.

The research group has accomplished the following results in 2019:

- Successful defense of PhD thesis:
 - Sander Ulp, “Algorithms for Learning and Adaptation Over Networks - Distributed Leader Selection”, supervisors prof. M. M. Alam and prof. Y. Le Moullec
- ETAG team grant PRG620 “CogniFlow-Cyte: Cognitronic Lab-on-a-Chip System for Highly-Automated Flow Cytometry”, prof. Rang, highest ranked evaluation in the engineering field
- Two events were held:
 - International workshop: 29 April - 2 May 2019, Leuven, Belgium: Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments (RACT-5G-IoT 2019);
 - Hackathon: 8-10.11.2019, Tallinn: Hackathon on Cognitive Electronics for Smart Environments.
- Selected publications:
 - Pardy, T.; Sink, H.; Koel, A.; Rang, T. (2019). Development of a Low-Cost, Wireless Smart Thermostat for Isothermal DNA Amplification in Lab-On-A-Chip Devices. *Micromachines*, 10 (7), 437;
 - Rashid, M. H.; Koel, A.; Rang, T. (2019). First Principles Simulations of Phenol and Methanol Detector Based on Pristine Graphene Nanosheet and Armchair Graphene Nanoribbons. *Sensors*, 19 (12), 2731;
 - Khan, S. Z.; Malik, H.; Sarmiento, J. L. R.; Alam, M. M.; Le Moullec, Y. (2019). DORM: Narrowband IoT Development Platform and Indoor Deployment Coverage Analysis. Workshop on Recent Advances in Cellular Technologies and 5G for IoT Environments 2019 (RACT-5G-IoT 2019).

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:

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

Major research projects:

- VFP15051 H2020 ERA-Chair “Cognitive Electronics” (01.12.2015 – 30.11.2019);
- IUT19-11 "Impedance spectroscopy based identification and control of objects: signals, algorithms, energy efficient solutions" (1.01.2014–31.12.2019);
- 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).

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

- Collaboration with SelfDiagnostics: the temperature control method demonstrated by the group was adapted to their Point-of-Care test device; moreover, a pilot study was conducted to digitally detect and wirelessly transmit test results for further analysis;
- VA16039 Batches of Ethercat modules and FPGA-IoC prototypes have been designed and produced for the European Spallation Source (ESS).

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
Hassan Malik, teadur
Sander Ulp, nooremteadur
Navuday Sharma, järeldoktor-teadur
Ali Masood, doktorant
Egon Astra, doktorant
Rida Khan, doktorant
Collins Burton Mwakwata, doktorant
Triin Kask, doktorant
Taavi Laadung, doktorant
Abdul Saboor, doktorant
Marika Kulmar, lektor.

Võtmesõnad: raadiovõrgu ressursside ja interferentsi haldus, madala võimsustarbega kommunikatsioonitehnoloogiad tervishoius, 5G (5. põlvkonna mobiilside), NBIoT (kitsaribaline asjade Internet), BAN.

Uurimisrühma teadus- ja arendustegevus on suunatud raadiovõrgu ressursi ja interferentsi haldusele traadita sides: tehnikad ja algoritmid võimaldamaks 5G raadiosidet, 5G testikeskkonna arendamine, mh suure arvu masinate vahelise lairiba-mobiilside 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 2019. aastal:

- Kaks edukat doktoritöö kaitsmist:
 - Sander Ulp, "Õppimisalgoritmid hajutatud võrkude tarbeks – juhtsõlme hajus valimine", juhendajad prof. M. M. Alam ja prof. Y. Le Moullec;
 - Egon Astra, "Edastusfiibri mittelineaarsete mõjutuste vähendamine optilistes sidesüsteemides faasitundlike parameetriliste võimendite abil", juhendajad prof. P. A. Andrekson and prof. T. Ruuben.
- Panus rahvusvaheliste standardite arendamisse:
 - ETSI SmartBAN standard, tööartikli DTR/SmartBAN-0014, "SmartBAN MAC (TS 103 325) rakendamine erinevatele kasutuslugudele" raport;
 - *IEEE Green ICT Energy Efficient Communication Hardware (EECH) standard*, P1923.1 standard sidesignaali laine kujusid töötlevate seadmete energiatõhususe ülemise piiri arvutamiseks.
- Valitud publikatsioonid:
 - SR Biyabani, R Khan, MM Alam, AA Biyabani, E McCune, "SS5G: Energy Efficiency Evaluation of Linear Transmitters for 5G NR Wireless Waveforms", *IEEE Transactions on Green Communications and Networking*, Vol. 3 (2), lk: 446 – 454, 2019.

- H Malik, MM 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”, IEEE Networks Magazine, lk: 1-8, 2019 (DOI: 10.1109/MNET.001.1900087).

Uurimisrühma seotus TalTechi AAK prioriteetse suunaga:

- Targad ja energiatõhusad keskkonnad.

Uurimisrühma tegevusega seotud teadusvaldkond:

2.2 Elektrotehnika, Elektroonika, infotehnika.

Olulisemad projektid:

- VFP15051 H2020 ERA-Chair “Kognitiivne elektroonika” (teostatud).
- VNT18039 NATO SPS Public Safety Communication in the Context of Terrorists Attacks (01.06.2018-01.05.2021)
- PRG424 ETAg Tagasisidestatav andmevahetussüsteem kõrge reaktiivsusega abistava neuromuskulaarse stimulatsiooni võimaldamiseks (01.01.2019-31.12.2023).

Info uurimisrühma rakendusliku väljundiga teadus- ja arendustegevuse kohta:

- LEP19033 Rakendusuuring firmaga Domotics OÜ „NSP203 - Kiuto hooneautomaatika süsteemi probleemsete komponentide rakendusuuring ja tootearendus “ (rahastus: Archimedes SA/NUTIKAS meede)
- LEP19100 TA leping ettevõttega Huawei Corporation, kantavate seadmete arendamine heaolu tagamiseks.

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
Hassan Malik, researcher
Sander Ulp, early stage researcher
Navuday, post-doc researcher
Egon Astra, doctoral student
Ali Masood, doctoral student
Rida Khan, doctoral student
Collins Burton Mwakwata, doctoral student
Triin Kask, doctoral student
Taavi Laadung, doctoral student

Abdul Saboor, doctoral student
Marika Kulmar, lecturer, doctoral student

KEYWORDS: radio resource and interference management, 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 2019:

- Two successful defences of PhD thesis:
 - Sander Ulp, “Algorithms for Learning and Adaptation Over Networks - Distributed Leader Selection”, supervisors prof. M. M. Alam and prof. Y. Le Moullec
 - Egon Astra, “Transmission Fiber Nonlinearity Mitigation in Optical Communication Links Using Phase-Sensitive Parametric Amplifiers”, supervisors prof. P. A. Andrekson and prof. T. Ruuben
- Contributions in International Standards:
 - In ETSI SmartBAN standard, “Rapporteur” of work item: DTR/SmartBAN-0014, “Applying SmartBAN MAC (TS 103 325) for various use cases”
 - In IEEE Green ICT Energy Efficient Communication Hardware (EECH) standard, P1923.1 Standard for computation of energy efficiency upper bound for apparatus processing communication signal waveforms
- Selected publications:
 - SR Biyabani, R Khan, MM Alam, AA Biyabani, E McCune, “5G: Energy Efficiency Evaluation of Linear Transmitters for 5G NR Wireless Waveforms”, IEEE Transactions on Green Communications and Networking, Vol. 3 (2), pp: 446 – 454, 2019.
 - H Malik, MM Alam, H Pervaiz, Y Le-Moullec, A Al-Dulaimi, S Parand, L Reggiani, “Radio Resource Management in NB-IoT Systems: Empowered by Interference Prediction and Flexible Duplexing”, IEEE Networks Magazine, pp: 1-8, 2019 (DOI: 10.1109/MNET.001.1900087)

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:

2.2 Electrical Engineering, electronics engineering, information engineering

Major research projects:

- VFP15051 H2020 ERA-Chair “Cognitive Electronics” (01.12.2015 – 30.11.2019, Completed)
- 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:

- LEP19033 Applied Research Agreement with Domotics OÚ for enhancement of Kiuto smart building system's problematic components (project financed by Archimedes SA with NUTIKAs measure)
- LEP19100 Research and Development Agreement with Huawei Corporation regarding development of wearable device for well-being