INFOTEHNOLOOGIA TEADUSKONNA RAADIO- JA SIDETEHNIKA INSTITUUDI TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2011

1. Instituudi struktuur

Instituudi direktor Andres Taklaja

- Mikrolainetehnika õppetool, Chair of Microwave Equipment, Andres Taklaja
- Raadiotehnika õppetool, Chair of Radio Engineering, Toomas Ruuben
- Signaalitöötluse õppetool, Chair of Signal Processing, Tõnu Trump
- Telekommunikatsiooni õppetool, Chair of Telecommunications, Eerik Lossmann
- Elektromagnetilise ühilduvuse teaduslaboratoorium , Electromagnetic Compatibility Laboratory

2. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

(NB! punktid 2.1- 2.6 täidab struktuuriüksus)

2.1 struktuuriüksuse koosseisu kuuluvate uurimisgruppide

2.1.1 teadustöö kirjeldus (*inglise keeles*);

There are four research groups at the Department of Radio and Communications Engineering:

<u>Microwave Engineering Research Group</u> (Prof. Andres Taklaja)

Objectives of the Microwave Engineering Research Group were designing, prototyping, laboratory and field testing of Radio-Controlled Improvised Explosive Devices (RCIED) jamming devices.

<u>Signal Processing Research Group</u> (Prof. Tõnu Trump)

Research at the Signal Processing Research Group has been focused on two main areas – adaptive algorithms and cognitive signal processing together with spectrum sensing.

<u>Radio Wave Propagation Research Group</u> (Assoc. Prof. Eerik Lossmann, Assoc. Prof. Urve Madar)

Research activities at the Group involved received signal level and background noise level measurements at a number of shortwave receiving sites in Estonia for the purposes to describe statistically medium-length shortwave radio communications channels according to the Rician fading channel model.

<u>Man-Machine Relationship Research Group</u> (Assoc. Prof. Toomas Ruuben)

Man-Machine Relationship Research Group is participating in international project CARDINAL supported by EDA (European Defence Agency). Our group has been focused on two main areas of the project – intelligent perception support and decision support in military conditions.

2.1.2 aruandeaastal saadud tähtsamad teadustulemused *(inglise keeles).*

Main results of the research:

<u>Microwave Engineering Research Group:</u>

R&D activities at the Group resulted in successful prototyping and testing of the following equipment:

1) Portable and vehicle-installed versions of specialized electromagnetic jamming equipment for mobile communications TG/MP;

2) Wideband multichannel radiomonitoring system;

3) Wideband direction finding equipment (2 pcs.);

4) Synchronizing device ST/V for radio-controlled equipment (programmable in VHF, UHF and GSM frequencies), source of a synchronizing signal, and synchronized jamming equipment (4 pcs).

<u>Signal Processing Research Group:</u>

In the area of adaptive algorithms work has been done on combinations of two adaptive filters. When designing an ordinary adaptive algorithm, one faces a trade-off between the initial convergence speed and the mean-square error in steady state. In case of algorithms belonging to the Least Mean Square (LMS) family this trade-off is controlled by the step-size parameter. Large step size leads to a fast initial convergence but the algorithm also exhibits a large mean-square error in the steady state and in contrary, small step size slows down the convergence but results in a small steady state error. The combination of two adaptive filters solves this trade-off by employing two filters that adapt simultaneously on the same input signal. One of the filters has a large step size allowing fast convergence and the other one has a small step size for a small steady state error. The outputs of the filters are combined through an adaptive mixing parameter λ(*n*) so that the output signal of the combination equals $y(n) = \lambda(n) y_1(n) + (1-\lambda(n)) y_2(n)$, where $y_i(n)$ is the output signal of *i*-th individual filter at time *n*. This way the combination can achieve both of the desired properties the same time.

The transient analysis of the combination has been performed and it has been shown that the learning curve (excess mean square error) of the scheme can be well approximated by

$$EA \approx \sum_{i=0}^{M-1} \omega_i E\left[\left(\lambda(n) v_{1,i}(n-1) + (1-\lambda(n)) v_{2,i}(n-1)\right)^2\right],$$

where ω_i is the *i*-th eigenvalue of the input signal correlation matrix $\mathbf{R}_x$, and $v_{k,i}(n-1)$ is the *i*-th element of the transformed weight error vector of *k*-th filter at discrete time *n*-1.

Besides of investigating the adaptive combination as such, attention was given to application of the combination in adaptive line enhancer. The adaptive line enhancer is a device that is able to clean a periodic signal from additive noise using adaptive processing of signals. The scheme was proposed and steady state performance of it was analyzed.

In the area of cognitive signal processing the work focused on spectrum sensing algorithms. Cognitive radio is radio that does not have preallocated spectrum but is itself able to locate available spectrum bands for its work. For this cognitive radio must be able to perform detection in order to find out if there is a licensed user in band of interest or not. Usually detection algorithms are designed with assumption of white Gaussian noise only. This assumption is unfortunately not always satisfied, particularly in urban environments there is also a considerable amount of man-made noise present. Man made noise has typically an impulsive character. A scenario where both Gaussian and impulsive noise were assumed to be present was investigated by the group. An energy detector that is insensitive to impulsive noise was proposed and its performance was analyzed. It was demonstrated that the proposed detector performs in presence of impulsive noise almost as good as the usual Gaussian assumption based detector if the impulses are not present.

Radio Wave Propagation Research Group:

The results of background noise level measurements on HF at various sites in Estonia showed significant deviations from the reference level given by ITU-R P.372. Local sources of interference create increased noise level at various site-dependent frequencies. Analysis of the noise level measurement results allowed us to make some general conclusions:

- The man-made noise power is mostly concentrated in the frequency range from 2 MHz to 5 MHz;
- There exist significant deviations from the theoretical curves. Sources associated with local peaks of background noise curves are often difficult to identify.

The received radio signal can be represented as a sum of specular and reflected components with a relatively stable specular component associated with surface wave and reflected components related to spatial wave. This propagation mechanism suggests the use a Rician fading channel model that can be statistically described by the power Ω of the specular component of received signal, and by the ratio *K* between the power of specular and reflected components. The received signal amplitude *x* is Rice distributed if its density function is given by:

$$f(x) = \frac{x}{\sigma^2} \exp\left(-\frac{x^2+\nu^2}{2\sigma^2}\right) I_0\left(\frac{x\nu}{\sigma^2}\right),$$

where $I_0(z)$ is the modified Bessel function of the first kind with order zero.
Parameters of the Rice distribution ν ja σ are related to the Rician fading channel parameters K and Ω as follows

$$\nu^2 = \frac{K}{1+K}\Omega \text{ and } \sigma^2 = \frac{\Omega}{2(1+K)}.$$

The power ratio K as a function of the Rice distribution parameters is given by

$$K = \frac{\nu^2}{2\sigma^2}.$$

Analysis of fading statistics allowed us to conclude that for medium length HF radio links with distances from 50 to 230 km over Estonian mainland the received signal power associated with surface wave dominates over the power of highly time-varying skywave component with the K parameter being mostly in the range from 2 to 9. Therefore the received signal level does not have strong fluctuations. Nevertheless, a HF communications system has to monitor a range of operating frequencies in order to find the frequency with the best achievable SNR, and to choose the output power. It is highly desirable to choose the optimal radiation angle of receiving antenna leading to the largest K parameter value, if possible. Research plans of the Group include the estimation of data link error performance on the basis of estimated K values for various shortwave propagation paths in Estonia.

Man-Machine Relationship Research Group:

Man-Machine Relationship Research Group is participating in international project CARDINAL supported by EDA (European Defence Agency).

The challenge in the CARDINAL project is to coordinate information flows such that military actors get the right information (no more and no less) at the right time. The project therefore aims to design and develop an information coordination system that will provide real-time tactical support to military troops on the ground while performing their tasks in urban environments. This support mainly involves a dismounted decision-maker and consists of partly autonomous a) fusing of heterogeneous information streams into information elements to increase situational awareness, and b) selection of the relevant information to improve the quality of decision-making. The most likely candidate to use this system would be the primary decision-maker on the ground – and link to higher level command – which is the Platoon Commander (PC). Yet, the PC and his group commanders are expected to carry PDAs or smart phones at most to maintain situation awareness (SA) in future soldier system configurations. We argue that PDAs and smartphones are not the right platform to provide tactical support to a PC, nor does the envisioned system simply provide typical SA elements: blue/red force tracking, and route planning elements. These elements will be provided by a typical Battlefield Management System (BMS). Man-Machine Relationship project, however, will also support in the decision-making process, involving larger amount of higher level information than strictly required by the PC, e.g. using current and historic data to make future predictions.

Our group focused at the development of perception support and decision support part of the project. Perception support can be defined as: "continuous extraction of environmental information, integration of this information with previous knowledge to understand a situation and anticipate future events". Therefore, perception support provides information about the status, attributes and dynamics of the relevant elements in the environment. It also includes the classification of information into representations and provides the basic building blocks to support decision processes. Furthermore, as a dynamic process, the system on a perception support level should be able to combine new information with already existing knowledge to produce a composite picture of the situation as it evolves.

To reach this challenging objective, one needs to correlate and/or fuse the data provided by smart sensors or human observation. The aim is to combine lower-level data to generate higher-quality information, and to improve situation awareness. Perception support is thus based on semantic information processing, information fusion and knowledge based inference reasoning. During the project a set of tools and techniques will be developed for analyzing and controlling the complex series of interrelated events that drive the current situation. The fusion of sensor data is realized by taking into consideration the semantics of the information, through a representation or model of the situation that we want to perceive. In this context, a situation is viewed as a combination of several situation elements or smaller situations, each of them appearing at some place in time.

Perception support in the current project will essentially be developed and provided for:

- Object detection and identification, e.g. detecting and identifying a vehicle on the street. Our group works with the several audio processing algorithms to detect vehicles and weapons
- Fusing real-time information from sensing devices and intelligence databases. In this context two types of relevance assessment need to be done to determine which of the sensors/databases provide the most meaningful data. First, the system needs to distinguish between noise and signals and determine which sensor(s) deliver the best quality signal to build an information element. In addition, 'meaningful data' entails not only the differentiation between signal and noise, but also the level of relevance for the Information

Manager. Given the current situation during the mission, the mission goals and the PC's intents, some information is more relevant than other in focusing the operator's attention, e.g. visual/auditory/tactile information.

Decision support in the current project:

- Intelligent path planning algorithm. Several path planning algorithms are modelled in MATLAB environment. At the moment our group is working on integration of path planning algorithm into Google Map-based application and LabView environment which will be a basis of the CARDINAL workstation.

2.2 Uurimisgrupi kuni 5 olulisemat publikatsiooni läinud aastal.

Signal Processing Research Group:

1. Trump, T. (2011). A combination of two NLMS filters in an adaptive line enhancer. In: Proceedings: 17th International Conference on Digital Signal Processing, 6-8 July, Corfu, Greece. IEEE, 2011, 1 - 6.

2. Trump, T; Müürsepp, I (2011). An Energy Detector for Spectrum Sensing in Impulsive Noise Environment. In: IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2011): Toronto, Canada, September 11-14, 2011. IEEE, 2011, 467 - 471.

3. Trump, T. (2011). Output signal based combination of two NLMS adaptive filters -- transient analysis. Proceedings of Estonian Academy of Sciences, Vol. 60, No. 4, 258 - 268.

4. Trump, T. (2011). Output statistics of a line enhancer based on a combination of two adaptive filters. Central European Journal of Engineering, 1(3), 244 - 252.

5. Trump, T.; Müürsepp, I. (2011). Robust Spectrum Sensing for Cognitive Radio. In: Proceedings of the 19th European Signal Processing Conference (EUSIPCO 2011): European Signal Processing Conference (EUSIPCO2011), Barcelona, 29.08-02.09.2011. EURASIP, 2011, 1224 - 1228.

Radio Wave Propagation Research Group:

1. Lossmann, E.; Meister, M.-A.; Madar, U. (2011). Noise level estimation in the shortwave frequency range. Electronics and Electrical Engineering, 6, 85 - 88.

2. Lossmann, E; Meister, M.-A.; Madar, U. (2011). On HF communication link parameter estimation in the Baltic region. In: Proceedings of the IEEE APWC '11: IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications, Torino, Sept. 12-16. IEEE, 2011, 812 - 814.

Man-Machine Relationship Research Group:

1. Berdnikova, J.; Koževnikov, V.; Ruuben, T.; Raja, A. (2011). Data Post-Processing Algorithms for Active Forward-Looking Sonar System. Electronics and Electrical Engineering, 110(4), 43 - 46.

2.3 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

2.4 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

2.5 Aruandeaasta tähtsamad T&A finantseerimise allikad.

1. Kaitseministeeriumiga sõlmitud T&A leping „Raadiojuhtimisega süsteemide talitluse monitooring, häirimine ja neutraliseerimine" 2007-2011 (leping 7113L).

2. Euroopa Kaitseagentuuriga (*European Defence Agency*) sõlmitud T&A leping „Inimene-seade koostöövõimekuse uuringud efektiivsemaks otsuste tegemiseks lahinguolukorras linnatingimustes" (*Capability study to investigate the essential manmachine relationship for improved decision making in urban military environment*) 2010-2012 (leping VA461).

2.6 Soovi korral lisada aruandeaastal saadud T&A-ga seotud tunnustusi (va punktis 2.3 toodud tunnustused), ülevaate teaduskorralduslikust tegevusest, teadlasmobiilsusest ning anda hinnang oma teadustulemustele.

2.7 Instituudi teadus- ja arendustegevuse teemade ja projektide nimetused *(Eesti Teadusinfosüsteemi, edaspidi ETIS, andmetel)*

- Haridus- ja Teadusministeerium

sihtfinantseeritavad teemad:
baasfinantseerimise toetusfondist rahastatud projektid (sh TTÜ tippkeskused):
riiklikud programmid:

- Teiste ministeeriumide poolt rahastatavad riiklikud programmid:

- Uurija-professori rahastamine:

- SA Eesti Teadusfond

grandid:
ühisgrandid välisriigiga:
järeldoktorite grandid (SA ETF ja Mobilitas):
tippteadlase grandid (Mobilitas):

- Ettevõtluse Arendamise SA

eeluuringud:
arendustoetused:

- SA Archimedesega sõlmitud lepingud

infrastruktuur (nn „mini-infra", „asutuse infra"):
Eesti tippkeskused:
riiklikud programmid:
muud T&A lepingud:

- SA Keskkonnainvesteeringute Keskusega sõlmitud lepingud:

- Siseriiklikud lepingud:

– LEP7113 Raadiojuhtimisega seadmete häirimine (14.11.07 – 30.06.11), Kaitseministeeriumi teadusgrant (0,68 MEUR), Taklaja Andres

– LEP 11051 Signaalide aeg-ruumilise töötlemise algoritmide arendus (30.06.11-30.06.12) Rantelon OÜ uurimistöö (0,1 MEUR), Taklaja Andres

- EL Raamprogrammi projektid:

- Välisriiklikud lepingud:

– VA461, Capability study to investigate the essential manmachine relationship for improved decision making in urban military environment (01.04.10-30.11.12), EDA uurimistöö (0,158 MEUR), Taklaja Andres

2.8 Struktuuriüksuse töötajate poolt avaldatud sihtfinantseeritava teadusteema taotlemisel arvestatavad eelretsenseeritavad teaduspublikatsioonid *(ETIS klassifikaatori alusel 1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1 ja 5.1).*

1.1

Berdnikova, J.; Koževnikov, V.; Ruuben, T.; Raja, A. (2011). Data Post-Processing Algorithms for Active Forward-Looking Sonar System. Electronics and Electrical Engineering, 110(4), 43 - 46.

Lossmann, E.; Meister, M.-A.; Madar, U. (2011). Noise level estimation in the shortwave frequency range. Electronics and Electrical Engineering, 6, 85 - 88.

Trump, T. (2011). Output signal based combination of two NLMS adaptive filters – transient analysis. Proceedings of Estonian Academy of Sciences, Vol. 60, No. 4, 258 - 268.

Ainomäe, A.; Rokk, I.; Lossmann, E. (2011). Teaching of telecommunication-specific university course in cooperation with partners from industry. Electronics and Electrical Engineering, 4, 131 - 134.

1.2

Trump, T. (2011). Output statistics of a line enhancer based on a combination of two adaptive filters. Central European Journal of Engineering, 1(3), 244 - 252.

1.3

Ornovskis, M. (2011). Aspects of High Availability and Load Balancing in Logging Infrastructure. Молодой ученый, 1(4), 93 - 96.

2.1

2.2

3.1

Trump, T. (2011). A combination of two NLMS filters in an adaptive line enhancer. In: Proceedings: 17th International Conference on Digital Signal Processing, 6-8 July, Corfu, Greece. IEEE, 2011, 1 - 6.

Trump, T; Müürsepp, I (2011). An Energy Detector for Spectrum Sensing in Impulsive Noise Environment. In: IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2011): Toronto, Canada, 11-14 september 2011. IEEE, 2011, 467 - 471.

Lossmann, E; Meister, M.-A.; Madar, U. (2011). On HF communication link parameter estimation in the Baltic region. In: Proceedings od the IEEE APWC '11: IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications, Torino, Sept. 12-16. IEEE, 2011, 812 - 814.

<u>3.2</u>

Trump, T. (2011). Transient Analysis of a Combination of Two Adaptive Filters. Lino Garcia Morales (Toim.). Adaptive Filtering (297 - 312).INTECH

Trump, T.; Müürsepp, I. (2011). Robust Spectrum Sensing for Cognitive Radio. In: Proceedings of the 19th European Signal Processing Conference (EUSIPCO 2011): European Signal Processing Conference (EUSIPCO2011), Barcelona, 29.08-02.09.2011. EURASIP, 2011, 1224 - 1228.

<u>3.3</u>

<u>4.1</u>

<u>5.1</u>

2.9 Struktuuriüksuses kaitstud doktoriväitekirjade loetelu *(NB! struktuuriüksus lisab struktuuriüksuse töötaja juhendamisel mujal kaitstud doktoriväitekirjade loetelu)*

2.10 Struktuuriüksuses järeldoktorina T&A-s osalenud isikute loetelu *(ETIS-e kaudu esitatud taotluste alusel)*

2.11 Struktuuriüksuses loodud tööstusomandi loetelu

3. Struktuuriüksuse infrastruktuuri uuendamise loetelu

- ZVH4 Kaabli ja antenni analüsaator, 4.07.2011, 18 211 €