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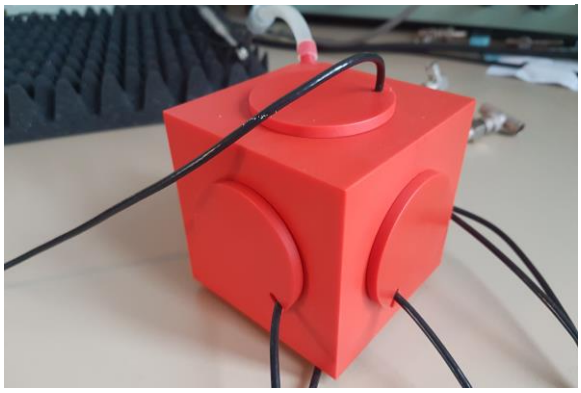

Cubical source array for airborne ultrasound

Welcome

After the first active year of the project it is a great pleasure to welcome you to the second scheduled newsletter. We greatly appreciate this opportunity to inform and update you about news, achievements and results of our work.

In the first period of the project, the focus was on the preparation of technical and practical prerequisites for the various studies and experiments planned in this project. New sound sources were constructed and manufactured for both the infrasound and ultrasound frequency ranges. They are capable of use in harsh environment conditions as for example in fMRI scanners, fulfil the demanding requirements of spectral purity, or will be applied in longitudinal studies with test persons. Stakeholders engagement intensified by establishing an advisory group which is already engaged in a consultation process for the new ear simulator. This consultation will be incorporated into the definition process for the final specifications of the ear simulator which will be completed in August 2017. Experiments using brain imaging and psychoacoustic methods in parallel have been prepared and are ready to start this summer.

The project team is already collaborating with potential users and beneficiaries of the project outcomes. The first conference presentations were given and contributions are published in journals and conference proceedings.

I hope you will find valuable information in this newsletter. We are keen to keep in contact with you as stakeholders, users, or as someone generally interested in the work, and we are looking forward welcoming you in our project community.

Christian Koch

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Coordinator

News and facts

- A stakeholder advisory group was established which is led by Graham Frost, UK.
- The first project progress meeting was held in January in Ljubljana, Slovenia.
- A stakeholder consultation was launched to complete the final specifications of the new ear simulator for meeting the requirements of potential users as close as possible.
- Two presentations were given at 12th ICBEN Congress on 'Noise as a Public Health Problem' in Zurich.

Highlights from the work packages

Design of universal ear simulator family

Based on stakeholder consultation it has been concluded that the universal ear simulator family shall consist of three different ear simulators, two representing children, at 3 months and 24 months of age and one representing adults. The three ear simulators will provide reference calibration points that can be supplemented with personalized correction for individual hearing tests.

The specifications of the universal ear simulator family will be based on the impedance data compiled in the literature study carried out in the first Ears project. A search for further published and unpublished data to support the specifications has revealed a gap the available knowledge and need for more detailed studies of the acoustic properties of ears, although comprehensive studies of middle ear reflectance have been pulished.

The design of practical implementations of the three ear simulators is in progress. It is the intention that the devices will be used as demonstrator devices at selected clinics during the project.

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Definition of a reference ultrasound workplace

IFA from DGUV and PTB defined a typical ultrasonic welding workplace setup that can serve as a reference for the variety of workplaces exposed to ultrasonic noise. The source is a standard ultrasonic welding machine by the collaborator Herrmann Ultraschalltechnik GmbH & Co. KG that can be used for different applications.

The methods currently used to measure and assess the ultrasonic noise at workplaces are adapted from those used in the audible frequency range. However it is one of the aims of the project to find a new method that is fast and appropriate to the ultrasound characteristics. In practice, such measurements are performed in running production lines with no opportunity to extensively study the method itself.

The reference workplace is now used at IFA and PTB to study in detail the ultrasound field and the applicability of current measurement methods in the laboratory. This strategy shall explain why the current methods lead to non-

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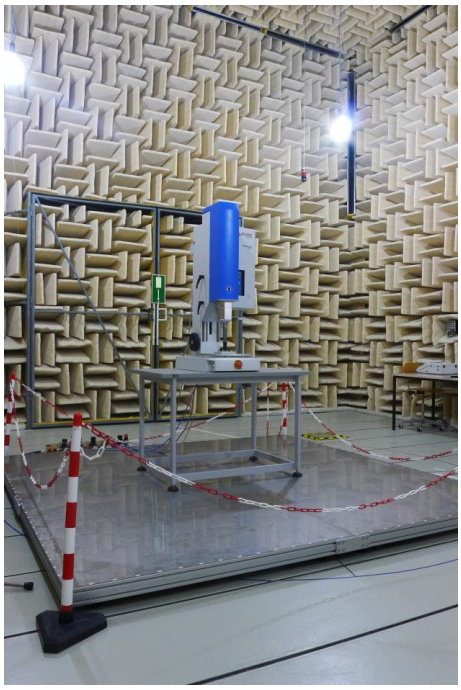
reliable results. The detailed knowledge on the sound field and how it is influenced by walls and the presence of the machine operator will allow a new appropriate method and its associated uncertainty to be found.



An ultrasonic welding machine on a desk in anechoic environment serves as a reference for noise-exposed working places.

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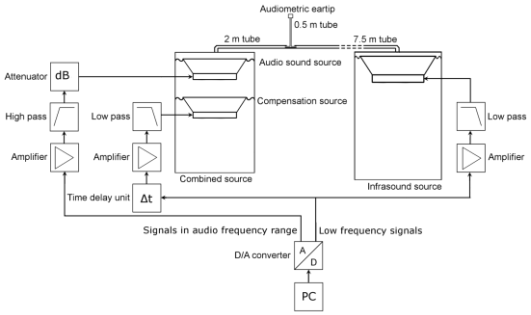
Special sound sources for "exotic" sounds (Infra- and Ultrasound)

Since the project focuses on the human sense of hearing, then researching the mechanisms of airborne infrasound (IS) and ultrasound (US) perception, only needs consider sound sources that couple directly to the ear canal, i.e., insert earphones. Owing to the targeted high sound pressure levels (SPL) for IS and US, the sources must operate most linearly (avoiding signal distortions) to avoid also generating sound at frequencies inside the conventional audio sound (AS) range. IS must not contain harmonics (multiple of fundamental frequency), US must not contain subharmonics (partials of fundamental frequency).

Sources for investigating the ***perception of IS accompanied by AS*** **have** also be able to generate the sum of the stimuli in a way preventing the generation of unwanted modulation frequencies. The figure below shows a schematic of the sound delivery to the ear.



Setup for detection threshold measurements of infrasound combined with audio frequency sound

Modulation frequencies do arise when the IS loudspeaker exerts its sound pressure on the AS loudspeaker membrane via the necessary conjunction of the sound tubes. The high-level IS then modulates the AS, as shown in the figure below, the spectrum (blue curve), generating modulation tones that become perceptible once their level difference to the AS tone becomes smaller than a certain limit (e. g., 38 dB for 1 kHz, 70 dB SPL, 4 Hz IS).

To prevent that impact, the AS source was equipped with an additional loudspeaker that delivers the IS signal to the back of the AS loudspeaker membrane, compensating the IS loudspeaker's influence. As shown in the same figure (red curve), the Modulation tones are reduced by more than 15 dB, making the effect imperceptible.

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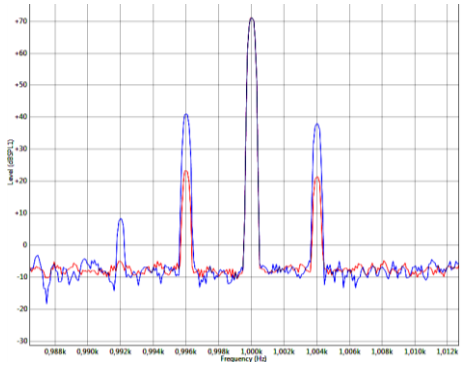
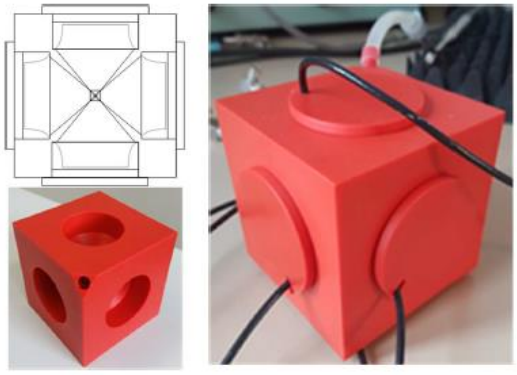


Spectra of sound produced by the source: in blue, the sound pressure spectrum of the perceptible modulation of a 1 kHz tone, 70 dB SPL, by an IS tone of 4 Hz, 124 dB SPL; in red, the reduced magnitude at 996 Hz and 1004 Hz, shifting the modulation below perception threshold.

For the generation of ***pure-tone US*** up to 40 kHz, which is intended to be fed into a sound conducting tube with ear tip, it transpired after pre-tests with small piezo loudspeakers, that only the use of several loudspeakers in unison could yield sufficiently high SPLs for threshold and brain response measurements in both MEG and MRI studies. The following figure shows the chosen geometrical lay-out. This source is able to yield up to 130 dB SPL with sufficiently low signal distortion.



Cubical source array for airborne US (edge length 80 mm), for behavioural threshold measurements and brain imaging. Upper left: Cross section; Lower left: empty housing with circular funnels; Right: Complete source with 6 piezo loudspeakers, feeding lead

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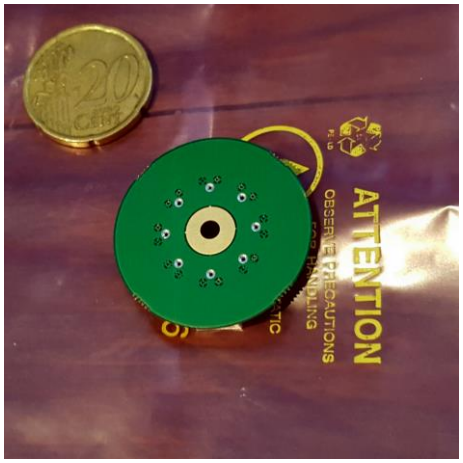
MEMS array for ultrasonic source location

A prototype device for locating sources of airborne ultrasound has been designed and produced, and is ready for testing. The device consists of an array of eight MEMS microphones optimised to operate in the ultrasound frequency range, and uses beam forming to localise the sound sources. While the presence of ultrasound may be determined with a single microphone, in an open public area, wide spatial distribution means that it is often difficult to find the source of the sound. The MEMS array and built-in video camera enables the sound field to be mapped onto a visual representation of the area to enable live identification of the source or sources of the ultrasound. The array is intended to support the measurement of ultrasound in public spaces.



MEMS array for the localisation of ultrasound sources. Notice the size of the device.

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Dissemination of work

Alongside the technical research, the consortium is also actively managing its planned dissemination activities and has devised a process of engaging with the most relevant individuals and groups, at the optimum time during the research to achieve identified goals. It is hoped that through this process, no opportunity will be missed to engage effectively with stakeholders to ensure that the project creates the greatest possible impact.

Stakeholder Advisory Group

The stakeholder advisory group (StAG) under the chairmanship of Graham Frost has been active in assisting with the specification of ear simulators. Stakeholders have been consulted on their views on how the new family of devices will be used in practice, and importantly how many devices are ultimately needed and what age groups they should cover. The StAG helped shape the questionnaire and individuals contributed their own valuable views alongside the range of general stakeholders who kindly provided responses.

EARS II at the ICBEN (Zurich, Switzerland)

Two presentations on results and prospects of the project were given at the 12th ICBEN Congress on Noise as a Public Health Problem which was held in Zurich, Switzerland from 18 to 22 June 2017. In a key note lecture the project coordinator introduced the audience into basic issues of the measurement, perception and assessment of infrasound and airborne ultrasound and in the same time presented first results of the project. A second contributed paper was presentation on a case study dealing with the determination of hearing thresholds of combinations of infrasound and audible sound. In this conference the focus lay on the question of how conclusions for wellbeing and safety could be drawn from the results of scientific studies and thus the presentations represented a unique possibility for dissemination of the project outcomes.

EARS II at the DAGA (Kiel, Germany)

IFA from DGUV and PTB had 4 contributions to the session “noise at working places” at DAGA (German Annual Conference on Acoustics) 2017 in Kiel. One talk and three poster presentations on the measurement, assessment and effects of ultrasound at working places attracted strong interest and led to intensive discussions. It was the first time that the topic created such an impact at a major conference like DAGA.

EARS II at International Congress on Sound and Vibration, London

The EARS II Consortium was present at the International Congress on Sound and Vibration, in London.

Internoise, Hong Kong.

Papers from the EARS II Consortium have been submitted to the International Congress for Noise Control (Internoise) in Hong Kong, to be held in August.

Incorporation of industry

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Two new collaborators were incorporated to the project. Herrmann Ultraschalltechnik GmbH & Co. KG is a leading manufacturer of ultrasonic welding machines and contributes with equipment and knowledge on the state-of-the-art of the technology.

BG ETEM is a German Social Accident Insurance Institution that brings knowledge and data on the measurement of ultrasonic noise at working places. Moreover, BG ETEM will test the newly developed assessment method in field tests under real world conditions.

Both collaborators make important contributions to one of the main tasks of the project to make ultrasonic noise measurable and assessable.

Business card of partners:

In this column of every Newsletter we introduce one or two of the institutes from the consortium to you. In this issue we present the University of Oldenburg's Medical Physics group from Germany, and the Laboratory of Metrology and Quality from University of Ljubljana, Slovenia.

The **Medical Physics group at Oldenburg University** performs interdisciplinary research in five research sections covering the fields Auditory Neurosensory Science, Computational Audition, Digital Hearing Devices, Psychoacoustics, Modelling & Evaluation, as well as Speech & Audiology. The group is part of the Department of Medical Physics and Acoustics, which is now located in the relatively young faculty of Medicine and Health Sciences at the University of Oldenburg. Whilst the medical school in Oldenburg has only been founded three years ago, the Medical Physics group has been located in Oldenburg since 1993 (formerly being part of the Physics Department), and was initially founded by Birger Kollmeier in 1986 at Drittes Physikalisches Institut at the University of Göttingen.

The main research stream is to investigate the properties of the normal and the impaired auditory system, both with psychophysical and physiological methods, and to apply this knowledge to areas with important practical problems, such as automatic speech recognition, optimization of diagnostic methods for hearing disorders, and noise reduction in hearing aids using "intelligent" signal processing strategies that can adapt to the respective acoustical situation. Although the scope of this work includes aspects from medicine (i.e., ENT medicine, audiology), psychology (psychophysics, perception research), neurobiology (EEG recording and analysis, neuroimaging), communication engineering, and computer science, the principle approach to tackle the main issues in our work originates from physics. Based on empirical data, we attempt to model the underlying processes. The model is again tested against real data.

The work for the EARS-II project in Oldenburg is based at the section for Auditory Neurosensory Sciences (PI: Stefan Uppenkamp) with in the Medical Physics group. Overall, the research aims at finding neural correlates of psychoacoustic performance in human listeners. Our goal is to understand how sound pressure entering the

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ears leads to a representation of what we hear, and how sound is represented along the ascending auditory pathway and cortex. Our research covers topics on sound localisation, loudness, modulation, pitch perception, and sound representation in normal, hearing impaired, and cochlear implant listeners. This work has now been extended towards the high and low frequency range, i.e. to frequencies outside the "classical" range of human hearing. Our methods include Psychophysics, Electroencephalography (EEG) and Magnetoencephalograhy (MEG), as well as functional magnetic resonance imaging (fMRI) of the human auditory system.

The Medical Physics group has moved to a new lab building in 2014. The lab space in this building is shared with other research groups within the Medical Faculty, including people from the Department of Psychology as well as other groups from applied physics and signal processing. A 3-Tesla MRI scanner and a 306-channel MEG system are in operation since January 2016. The facilities in the lab building are used for research projects only and not for the daily clinical routine work.

A 306-channel MEG system at Medical Physics group at University of Oldenburg

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The **University of Ljubljana** was founded in 1919 and it consists of 20 Faculties, 3 Academies and 3 University Colleges. It hosts 48000 undergraduate students. Faculty of Electrical Engineering includes 7 departments and 2000 undergrad students. 20% of the Faculty income is from EU research projects. Laboratory of Metrology and Quality (LMK) within Department of Measurements and Robotics is responsible for measurement and testing courses and coordinates the Quality Engineering Study Programme at the University of Ljubljana. LMK is part of the Slovenian National Metrology Institute (MIRS) and is a BIPM/EURAMET Designated Institute as it holds the Slovenian national standards for thermodynamic temperature and relative humidity. LMK is accredited according to ISO/IEC 17025 for calibration and testing and ISO/IEC 17043 for interlaboratory comparisons as proficiency testing provider.

Activities in LMK are focused on general metrology (all aspects of scientific, legal and industrial metrology), measurement theory and metrology, measurement of physical quantities, biomedical instrumentation, etc. Some fields of the LMK expertize are electromagnetic measurements, precision magnetic flux density measurements (NMR, optical magnetometry, MEG), acoustics, static and dynamic temperature measurements, humidity in gases, pressure measurements in gases, moisture in polymers, electric safety, biomedical instrumentation (ear thermometers, thermographic cameras and non-invasive blood pressure), psychophysiology (skin temperature, skin conductance, continuous blood pressure measurement, non-contact and

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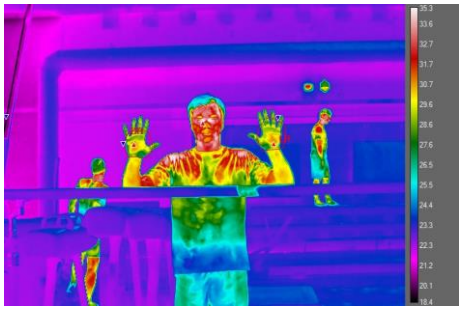
contact heart rate and heart-rate variability, respiration), measurements in sports.



Psychophysiology using thermography at LMK

The work within the EARS-II project is focused on design and evaluation of three stage questionnaires for identification of individuals extremely perceptible to non-audible sounds, who could be recruited for the brain scanning parts of experiments. The questionnaire will be used in several other tasks within work-packages of the EARS-II project.

Visit the Laboratory of Metrology and Quality
http://www.lmk.fe.uni-lj.si

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