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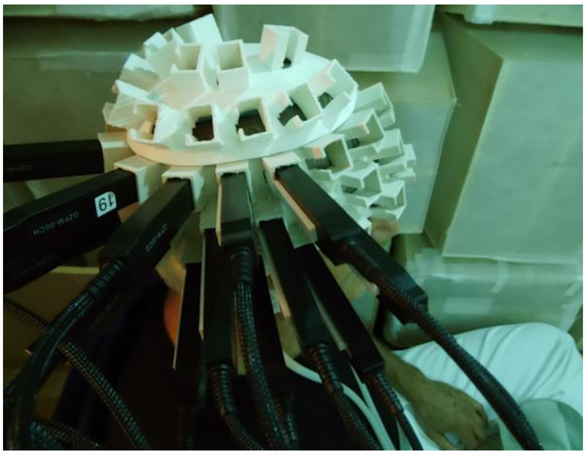

Individualized anatomy derived sensor holder for magnetoencephalography using OPMs

Welcome

The project "*Metrology for modern hearing assessment and protecting public health from emerging noise sources*" is entering the final straight now. A very intensive working phase is running, in which we are pleased to present the fourth project newsletter. Since the project has made serious progress we focus in this newsletter to results and the opportunity to present these outcomes to our stakeholders, users and interested persons. We greatly appreciate the opportunity to inform and provide update to you about news, achievements and results of our work.

A very efficient way to present results of the project to the scientific community, stakeholders, and users are the three workshops which will be held in the first quarter of year 2019. They cover the complete spectrum of project activities: One workshop to be held in Rostock, Germany deals with the perception and assessment of infrasound, a second one in London, UK focusses on similar issues for airborne ultrasound. The third workshop, taking place in Copenhagen, Denmark will present the new ear simulators and the issues of calibration, characterization and application. In these workshops many interesting results of our project work will be presented together with key note lectures of known experts, results from other projects and input from stakeholders and users. At all sessions time enough is scheduled to allow a wide and prosperous discussion of all issues.

The project team is strongly interested in coming into contact to the potential users and applicants of the project outcomes. We cordially invite you to join us at these events.

Christian Koch
Coordinator

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

News and facts

- Three workshops are going to take place, soon:
    - **Airborne ultrasound** (31.1.2019, London UK)
    - **New generation of ear simulators** (19.2.2019, Hørsholm, DK)
    - **Impact of infrasound** (18.3.2019, Rostock, DE)
- https://www.ears-project.eu/3662.html
- Comparative calibrations of the new ear simulators were performed and the dependence of its performance on environmental parameters determined.
- The third project progress meeting was held in Naerum, Denmark in June 2018.

Highlights from the work packages

Magnetoencephalography using Optically Pumped Magnetometers and anatomy derived sensor holder

Measurements of magnetic fields associated to electrical activity of the human brain (magnetoencephalography, MEG) are mainly done by Superconducting Quantum Interference Devices (SQUIDs), requiring expensive cooling and providing no geometric adaptability. Over the past decade, optical magnetometry has seen a rapid progress, offering an uncooled alternative for SQUIDs, Optically Pumped Magnetometers (OPMs).

OPMs have a limited bandwidth as a consequence of their physical properties, which makes them suitable for measurements of brain responses, especially due to hearing. They can detect MEG signals of a typical bandwidth from 1 to 100 Hz, being at the same time insensitive to electro-magnetic fields at ultrasound frequencies generated by ultrasound sources.

Due to their small dimensions and flexible wiring, OPMs can be placed directly on the human scalp in a great proximity to signal sources in the human brain, leading to an increase in the magnitude of the measured signal. To make the most of optical magnetometry advantages we designed an anatomy derived sensor holder. We extracted the head surface from anatomical magnetic resonance images and used it as input data for a CAD model of an individualized sensor holder. The holder consisted of three rows of slots designed to house the OPMs perpendicularly to the head surface and was 3D-printed with flexible PLA filaments.

For pilot measurements, fifteen dual channel OPMs were inserted into the head-shell sensor holder covering a region between F4 and P4 and centered around C4 (naming according to the international 10-20 system of the EEG electrode placement). The OPM- and SQUID-MEG signal was recorded in sequence as subjects performed a listening of 250 pure 1 kHz sine tones with a sound pressure level of 90 dB presented binaurally via tube earphones.

The data recorded with the OPM sensor array showed the brain response 100 ms after the stimulus onset (M100) as well as an early auditory brain response M50 (50 ms after the stimulus onset). In SQUID-based measurements the M50 response is not well visible, but the magnetic dipole 100 ms after the stimulus onset is clearly seen, especially for

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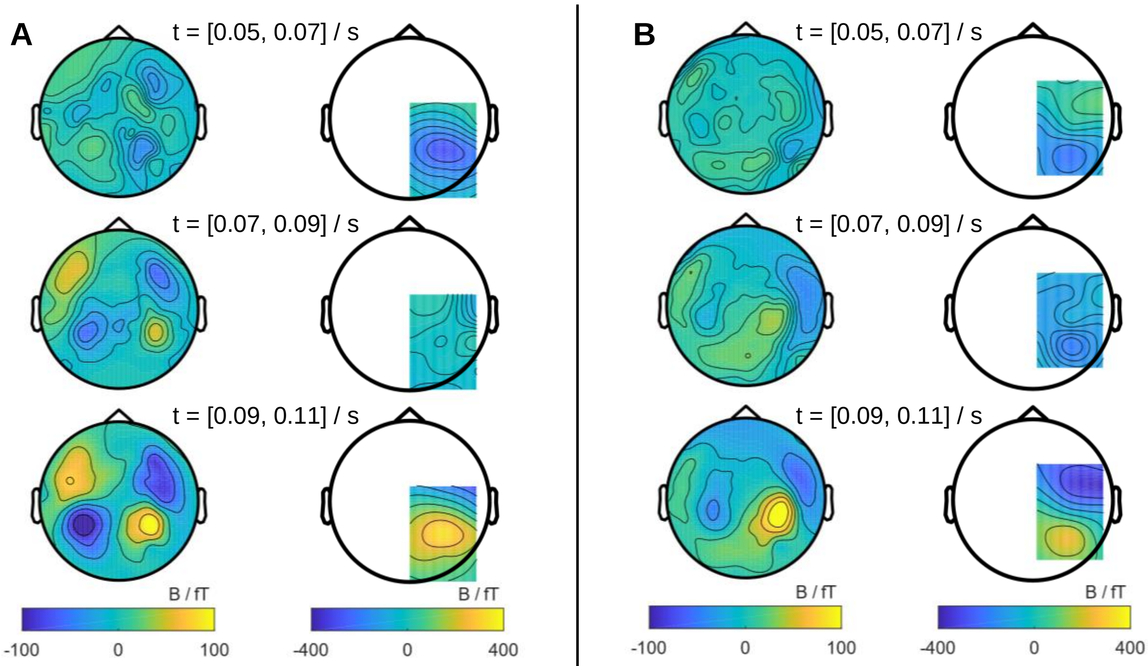

Magnetic field distribution maps for two subjects (A and B) obtained with SQUID-MEG (left column in each picture) and OPM-MEG (right column)

subject A. Due to the head dimensions, the OPMs did not fully cover the frontal side of the head and thus only the negative M50 brain response (and the corresponding depolarization M100) can be seen. The smaller head of subject B resulted in a clear magnetic response obtained with OPMs and the anatomy derived sensor holder. Data recorded with the SQUID-MEG system showed magnetic dipole only on the right side of subject's head.

The auditory evoked magnetic brain responses obtained with OPMs had a 4 times higher amplitude comparing to SQUID MEG. The increase in the magnitude of the measured signal due to the possibility of minimizing subject-sensor distance is extremely important in measurements of brain responses due to hearing of ultrasound frequencies, for which a weaker magnetic field is expected.

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A new method for transient calibration of ear simulators

Many of the applications of ear simulators include the use of transducers that use short duration signals, mainly for hearing assessment in children. These applications include the calibration of otoacoustic emission probes, probes for the measurement of auditory evoked potentials, audiometers, etc. For these, the short duration stimuli used to elicit a response can be tone bursts, clicks, and chirps. Currently, the calibration of such a stimulus is made in terms of an equivalent steady-state signal with the same peak-to-peak amplitude as the stimulus. This can introduce considerable errors when determining the effective level of the stimulus. The first step of the process is to clearly determine the effect of the ear simulator on the short duration stimuli. This can be done with a calibration procedure that provides an accurate description of the form of the stimulus reaching the ear of the test subject.

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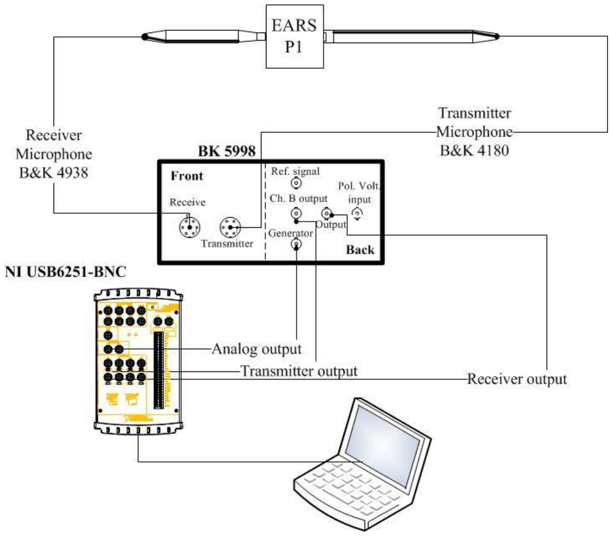

Schematic representation of the set-up for measuring the transient response of the ear simulator

The calibration procedure designed for this purpose converts a digitally captured output signal of the receiver microphone into the frequency domain by Fast Fourier Transform (FFT). A deconvolution is performed by simply dividing the output frequency response by the complex pressure response of the receiver microphone. Finally, the deconvolved signal in the time domain is obtained by applying an inverse FFT.

This calibration procedure has been tested on ear simulators developed in the earlier EARS project. The results show that WS3 microphones fitted to the EARS P1 devices used in this study have minimal influence on the acquired waveform, other microphones with a more limited bandwidth, included the microphones now known to be fitted to the EARS II devices, are likely to have greater effects.

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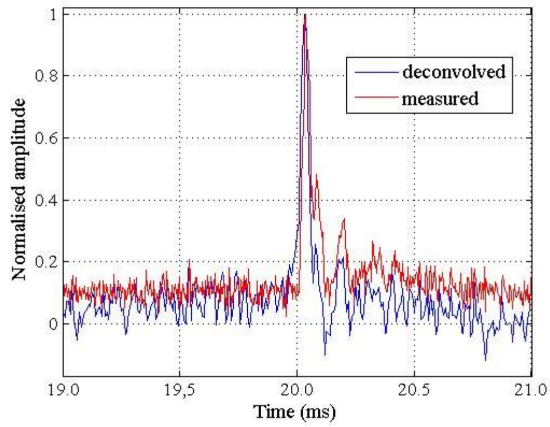

Microphone output signal and result following deconvolution of the microphone transient response

Development of a measurement procedure for airborne ultrasound

Field tests

In the previous issues of the newsletter (July 2017 and April 2018) the concept and establishment of a reference workplace to study the measurement of airborne ultrasound in the laboratory was described. Based on investigations at this reference workplace conducted by IFA and PTB, a draft of a new measurement procedure has been derived. The drafted measurement procedure provides a spatially averaging approach instead of static measurements, which are commonly used in the audible frequency range. After a review of this draft by practitioners and experienced measurement engineers, the procedure was applied to industrial workplaces as a field test to evaluate the practical applicability for occupational safety and health.

In total 19 workplaces at 8 different ultrasound machines were studied. The choice of machines included welding machines (non-food), cutting machines (food) and a leakage test device for bottles. The exposure patterns to ultrasound varied from single, distinct pulses over short series of pulses to continuous ultrasound

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emission. If available, different operational modes like different working frequencies or products were covered and additional measurements were performed at several characteristic spots at the machines.

The drafted measurement procedure turned out to be highly practical and could be carried out at all workplaces included in the field study.

Influence of the worker

Complementary to the field study, the reference workplace in the laboratory was used to systematically investigate the influence of a person, present in the ultrasound field, on the measurement result. At some industrial workplaces, the presence of the worker is necessary to operate the machine. Hence, a measurement of the ultrasound exposure can only be performed in the presence of a worker at the workplace. The developed draft for a new measurement procedure so far covers only measurements in the absence of a worker, but can be naturally extended. Therefore, a revised version of the draft was applied to a human subject research with 20 test subjects. Additionally, measurements with an artificial head were performed at the reference workplace to gain detailed knowledge on the characteristics of the altered sound field. The results will be included in a final draft of the measurement procedure.

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Longitudinal study: "effects of infra- and ultrasound on human cognition"

In our study on longitudinal effects of infra- and ultrasound on human cognition, psychopathology and brain structure & functioning, we have successfully managed to install and calibrate our sources in sleeping rooms all over the city of Hamburg, Germany. Until now, 30 participants are enrolled in the study. The subjects are exposed to the sound for 28 consecutive nights. Before and after the exposure, we run extensive test batteries, including measures of attention, memory, psychological well-being, and hearing capacity. We also conduct a functional magnetic resonance imaging session (fMRI), whereby we assess working memory. The test selection is thought to reflect typical areas of complaint that have been reported to be associated with exposure to infra- or ultrasound. In addition, we aim to identify individuals with particularly high sensitivity to low- and high-frequency sounds and are currently validating an according psychological questionnaire, which was developed with experts in several stages.

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Sound source installation in a sleeping room (note the source on the left).

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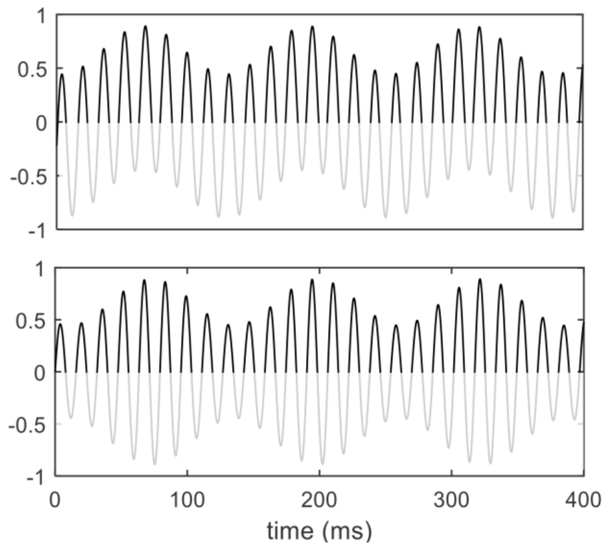
Amplitude modulation may be confused with infrasound

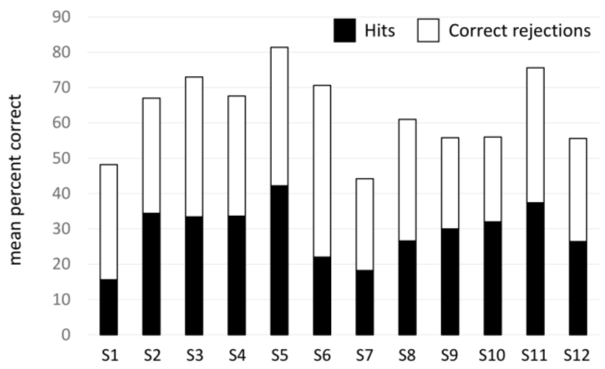
Environmental low-frequency noise (20-100 Hz) might contain pronounced envelope fluctuations with spectral content well below 20 Hz that listeners might easily confuse with infrasound. This disambiguity might underlie complaints about infrasound, even if such frequencies are actually not present in the noise that causes a nuisance. We showed that listeners indeed have great difficulty distinguishing between amplitude modulation and genuine infrasound. The figure below shows the simple sinusoidal stimuli types we used in the study: one containing true infrasound (upper panel) and one that is just amplitude-modulated (AM) at an infrasonic rate, however, does not actually contain frequency components below 20 Hz (lower panel).

The similar percept to both stimulus types can explained by cochlear physiology: Sensory cells in the inner ear release neuro transmitter only during basilar membrane movement in one direction (i.e., towards scala vestibuli). The signals become effectively half-wave rectified, an operation that is illustrated by greying out the lower parts of the signals, because they are not coded in the auditory nerve. Comparison of the remaining upper parts shows schematically that the spiking probabilities of the nerve in response to both stimuli are almost identical. Of course, this scenario is given only if the stimulus components are not spatially resolved along the basilar membrane.



The two stimulus types considered in this study: a biased tone (upper) and an AM tone (lower).

We tested whether listeners are able to distinguish a 63-Hz carrier tone, amplitude modulated at 8 Hz, from a 63-Hz pure tone that was perceptually loudness-modulated by an intense 8-Hz biasing tone. Also, a 125-Hz carrier tone was likewise used with similar results. Using a maximum-likelihood procedure, 12 participants first adjusted the intensity of the 8-Hz tone so that the perceived modulation of the pure tone matched a reference amplitude-modulated tone. The adjusted tones were in the range of 106 to 116 dB SPL. Both stimuli types were then presented in random order, and participants had to identify presentations which contained the infrasound tone. About half the 12 participants performed barely above chance (50%). The best subject had just 81% of the trials correct.



Discrimination performance of the 12 subjects. The length of each percent-correct bar is divided according to the contributions of hits and correct rejections to the total of the correct responses.

We speculate that other slowly amplitude-modulated low-frequency stimuli, which actually do not contain spectral content below 20 Hz, might also sound as they would contain infrasound. This finding may help to explain cases of annoyance attributed to infrasound, where measurements show audible low-frequency content, but with infrasound content well below sensation threshold.

For more detail see:
https://doi.org/10.3813/AAA.919232

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Dissemination of work

Project Workshops:

Three workshops will be held to present the results of the project and to step into discussion with users, manufacturers and everybody who is interested in our research:

Workshop Ultrasound

The workshop "Airborne ultrasound: assessing effects on the public and workers" (http://www.ears-project.eu/3663.html) will be held at 31 January 2019 in London, UK. It will focus on two questions:

- What are the effects of ultrasound exposure on humans?
- What measurement methods are appropriate for assessing exposure to ultrasound at a workplace and in public spaces?

The workshop provides an opportunity for those in science and industry to discuss the results of the EARSII project and related issues.

Workshop Ear Simulator

The workshop "A new generation of ear simulators" will be held at 19 February 2019 in Hørsholm, Denmark (http://www.ears-project.eu/3664.html). The workshop will demonstrate the design and production of new ear simulators to audiologists, manufacturers of audiometric equipment, calibration service providers and hearing researchers. Issues such as new calibration procedures, IEC standardization, determination of reference threshold data and guidance for implementing the new approach are all being covered.

Workshop Infrasound

The workshop "Perception and impact of infrasound on humans" (http://www.ears-project.eu/3665.html) will be held at 18 March 2019 in Rostock, Germany.

It will be held the day before the annual meeting of the German Acoustical Society (www.daga2019.de). It gives the opportunity to share the final results of the project with many interested persons and to discuss together all related issues of the topics. For this purpose the workshop schedule contains scientific talks and structured discussion sessions for a fruitful scientific exchange.

Past Events:

Results of the project were presented at various international conferences this year. Examples are:

- Euronoise conference in Greece,
- 25th International Conference on Sound and Vibration (ICSV) in Hiroshima, Japan
- 47th Internoise in Chicago, USA.
- 18th International Symposium on Hearing in Denmark

In all sessions interesting discussion developed showing the relevance of project results.

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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 METAS, the Swiss national metrology institute

View of METAS, Switzerland, www.metas.ch

METAS, the Federal Institute of Metrology, may be regarded as "the most accurate place in Switzerland". It serves as the federal center of competence for all issues related to measurement, measuring equipment and measuring procedures.

As such, its mandate is to ensure the availability in Switzerland of measurement and testing facilities with the degree of accuracy needed to meet the requirements of the economy, research and administration.

It fulfils its mandate in collaboration with third parties: In legal metrology with the verification laboratories as well as the cantons and their verification officers; in the dissemination of units with its designated institutes.

METAS stands at the cutting edge of measurement accuracy in Switzerland. It develops the national measurement base, that is to say it looks after the physical implementation, mutual comparison and thus the international recognition of measurement units. For this purpose, it operates the necessary laboratories and conducts the necessary research and development. It implements the Metrology Act; its other tasks are defined in the Federal Act on the Swiss Federal Institute of Metrology.

Activities in the field of acoustics are carried out by the laboratory of acoustics and vibration.

Our main effort is focused on the realization of the unit of measure used in various areas of acoustics and its dissemination by calibration of sound measuring equipment and references.

It is our mission to ensure in our country measurements, which are correct, and in compliance with the law serving the protection of man and environment. Concretely, this means, that we develop and maintain calibration facilities for calibrating specialized equipment used in such diverse areas such as building acoustics (e.g. tapping machines, impact sources, ...), engineering (microphones, sound level meters, sound sources, calibrators) and health (audiometric references such as artificial ears, artificial mastoids etc.).

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