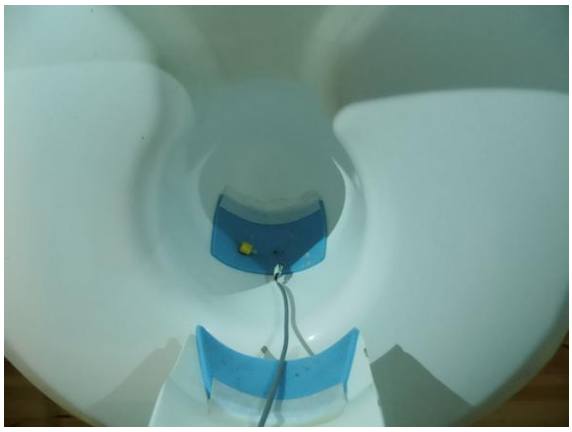
Ears Project **Newsletter No 3**

August 2013

Contents



MEMS transducer under evaluation for compatibility for use within the MEG test facility

Welcome

The project "*Metrology for a universal ear simulator and the perception of non-audible sound*" or *EARS*, has now been running for more than one year and we are pleased to present the third newsletter. The project work has been dominated by a detailed investigation of many technical and general aspects of the planned research programme.

The development of new analysis tools providing the technical basis for the measurement of brain response to non-audible sound is near completion and first test measurements have been carried out. A measurement setup has been established for generating and measuring a variety of ultrasound test stimuli with sufficient flexibility to enable the most appropriate types of stimulus to be evaluated. The modeling of ear simulators had been further improved to investigate critical structures for a universal ear simulator providing a rational basis for discussions on engineering and implement-ation of the final design.

I hope you find the newsletter to be valuable, and that you enjoy the material we present in this issue. As always, we are interested to keep in contact with you as stakeholders, users, or interested persons, so please do not hesitate to contact us.

Christian Koch
Coordinator

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News and facts

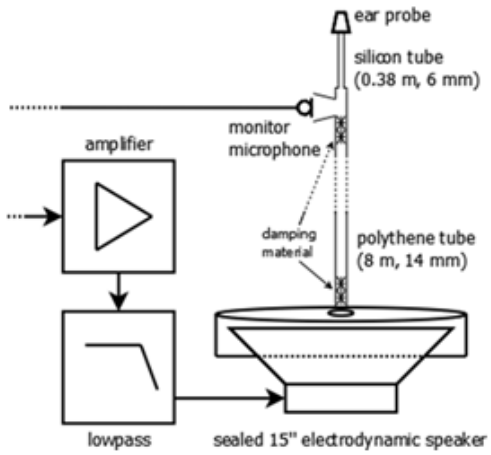
- A new researcher excellence grant (REG) for determination of brain responses using fMRI has been announced. High quality applications were received.
- The EARS project website has been update.
- The next project meeting will take place in Paris on 24/25 October 2013. Collaborators are invited to join the second day of the meeting. Registration details will be sent out shortly.

Highlights from the work packages

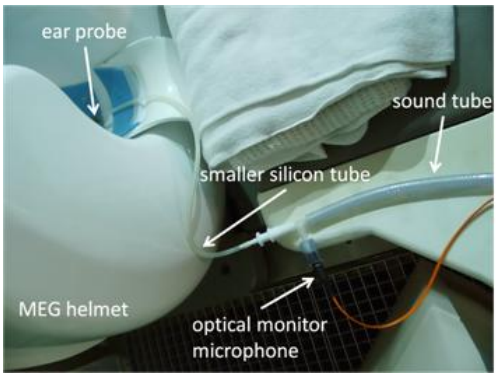
High-output infrasound source

A newly developed insert-earphone infra-sound source provides high dynamic range from 10 to 130 dB SPL with very low harmonicc distortions in the desired frequency range from 2 to 125 Hz.

The infrasound source is based on a loud-speaker with a strong electromagnetic motor system and stiff chassis, which is able to emit high sound pressure levels combined with very low distortion at low frequencies, which is essential for the intended application.



The loudspeaker is mounted in a wooden box that provides an airtight connection to the sound tube. To avoid any magnetic disturbance from the loudspeaker on the fMRI and MEG measure-ments, the driver unit has to be placed outside a minimum radius from the test environments. Acoustic stimuli are therefore delivered via a polythene tube terminated by an ear-tip for coupling to the test subject's ear. This tube is further filled with a specially selected sound absorbing material which effectively reduces the level of higher frequency harmonic components to below the normal threshold of hearing.

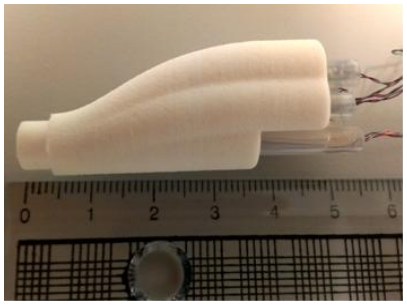


Tube delivery of the infrasound stimulus

In-ear ultrasound transducers

The first MEMS-based transducers for generating and measuring ultrasound stimuli have now been produced.

Simulations predicted that a system of four transmitting devices would be necessary to produce the requisite sound pressure level of over 100 dB.



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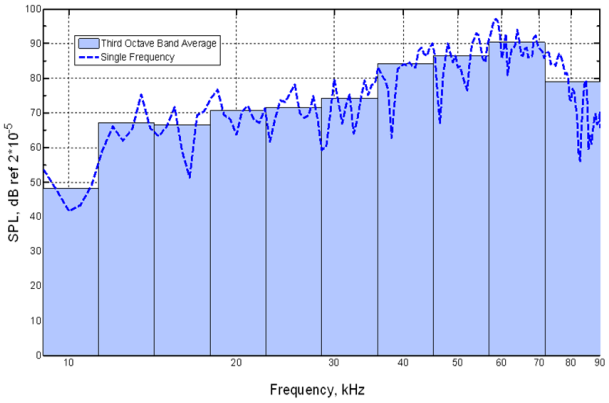
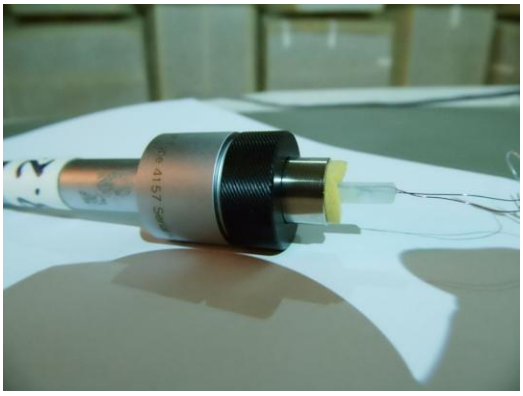
The picture above shows the final transducer assembly, which is intended to be coupled to a human ear via a foam ear plug around the 5 mm diameter acoustic output port. Initial measurements showed that with a conservative drive level, the SPL exceeded 90 dB between 60-70 kHz. The target of over 100 dB is considered easily achievable with an increased drive level.

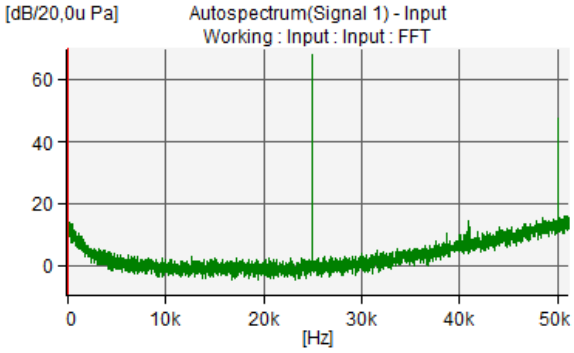


MEG compatibility of the ultrasound transducers

Tests have demonstrated that a MEMS ultrasound transmitter operating at 25 kHz does not interfere with magnetoencephalography recordings of brain magnetic fields.



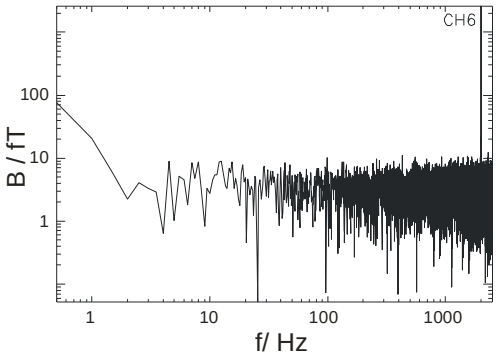
MEMS transmitter inserted in Brüel & Kjaer type 4157 occluded ear simulator.



SPL of MEMS transmitter driven with 1.77 V at 25 kHz. Peaks at 25 kHz and 50 kHz can be seen.

A MEMS transmitter was fitted into an occluded ear simulator using roll-fit foam as a seal, and the resulting SPL measured. These tests confirmed the transducer's suitability for ultrasound generation.

Since the transducers will be used within the MEG test environment, their potential to perturb the measurements has been evaluated. The figures below show the magnetic noise spectra of a SQUID sensor in close proximity to the MEMS transducer running at 2 kHz and 25 kHz respectively. The 2 kHz signal is visible, but the 25 kHz signal indicative of the stimuli to be used in the study, does not interfere with the magnetoencephalography device intended to record brain signals due to



Power spectrum of a MEG channel in the vicinity of the transmitter running at 2 kHz (note the line in the response at 2 kHz)

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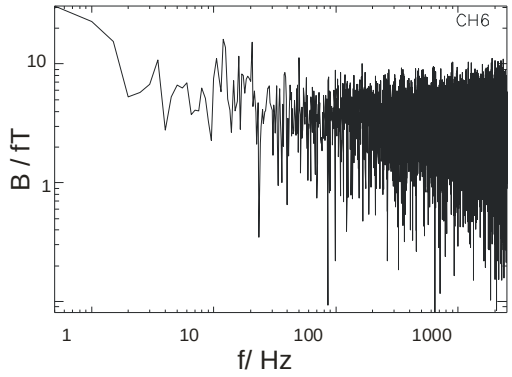


Power spectrum of the same MEG channel, but for the transmitter at 25 kHz (note the different y-axis scaling)

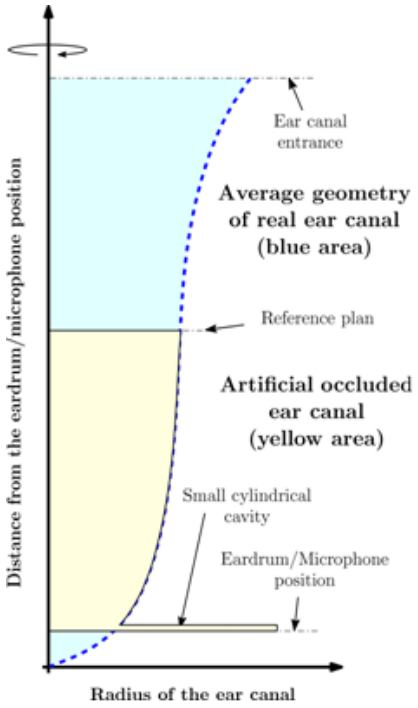
acoustic stimulation at ultrasound frequencies. The 25 kHz signal lies outside of the recording bandwidth of MEG system and it is therefore suppressed by the anti-aliasing filter.

Universal ear simulator design

The design approach being adopted for the universal ear simulator is to match both the acoustic input impedance and transfer impedance to that of average real ears. The input impedance governs the acoustic load presented to the test transducer and the transfer impedance relates the sound pressure developed at the ear drum to the input stimulus. These two conditions can be satisfied in two steps.

The acoustic transfer impedance condition depends on the ear canal geometry, so the proposed design of the artificial ear canal is based on a realistic geometry (the blue area in the figure). However, data is only available for the shape of adults ears. It is therefore being assumed that scaled versions of this shape can be used for other age groups. Furthermore, the artificial ear canal includes a small cylindrical cavity so as to ensure the coupling with the microphone, which is placed at its end (yellow area in figure).

The second step consists in imposing the appropriate acoustic terminal impedance near the microphone location in order to satisfy the acoustic input impedance condition.



Schematic real ear average geometry

Dissemination of work

One of the cornerstones of the EMRP, is that research projects should *create impact and benefits* for its stakeholders. This section provides a summary of recent dissemination activities.

Collaborations

The pool of stakeholder and collaborators engaged in the project continues to grow. Wolfson Microelectronics who initially

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supported the development of transducers though the provision of silicon components, now have an extended interest in the new microphone calibration capabilities developed in the project. A number of eminent medical professionals from Turkey, working across the spectrum of ENT research and audiology are also now engaged in the project.

New collaborators are always welcome. If you would like to have closer contact with the EARS project team, details of how to reach us can be found below.

Presentations

Various members of the project team have been active in presenting an overview of the project and progress on specific technical aspects, at a range of scientific conferences and key metrology meetings.

Chistoph Kling presented a paper on *Measurement techniques and assessment methods for airborne ultrasound* at the joint meeting of the Italian and German acoustical societies, AIA-DAGA 2013, in Merano, Italy.

Christian Koch presented a paper on *Traceable measurement of air-borne ultrasound* at the International Congress on Ultrasound, Singapore, and also made a further presentation on the project at Nanyang University of Singapore.

Richard Barham presented his paper, *A new study on human perception on non-audible sound* at the International Congress of Sound and Vibration, Bangkok. The paper gave an overview of the project as well as featuring the ultrasound transducer developments.

Christian Koch also presented an update on the project at EURAMET TC-AUV meeting in Prague. EURAMET TC-AUV is the forum for all European national measurement institutes involved in acoustics to discuss and co-ordinate their research.

The EARS project has also been featured as part of various external peer reviews of scientific activity at some of the participating institutes.

A number of further presentations at meeting and conferences are planned in the coming months, as well as the first journal paper submissions, so please look out for us.

Please also remember to check the project website for the latest updates.

http://www.ears-project.eu/emrp/ears.html

Business card of partners:

In this column of every newsletter we will introduce you to one of the institutes of the consortium. Today: Danish National Metrology Institute (DFM), Denmark.

DFM is the Danish National Metrology Institute, and the seat of DANIAmet, an umbrella organisation that coordinates the highly decentralised Danish Metrological System. DFM is a private enterprise fully owned by the Technical University of Denmark (DTU). DFM is also member of the Advanced Technology Group (GTS). This is a network of nine independent Danish organisations concerned with research and the development of new technology having as main purpose to provide capability and special

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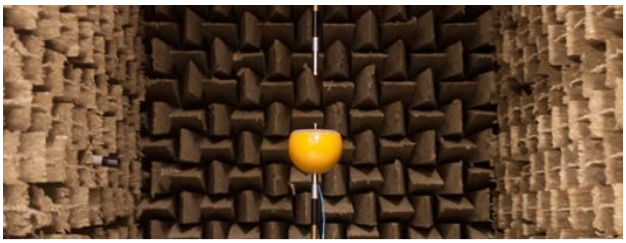
expertise to help companies and authorities with solutions to their technological and measurement problems.

DFM develops and maintains national measurement standards in the fields of Mass, Length (including nano-technology), Electricity, Electro-chemistry, Optics and Acoustics. DFM activities in these disciplines are always focused on fulfilling the needs of the Danish society. DFM's dissemination duties are carried out through calibration services, elaboration of reference materials, and consultancy services. Additionally, DFM collaborates with other laboratories under DANIAmet, industrial companies, and public authorities in order to ensure the quality and mutual recognition among Denmark's international trading partners of test and calibration carried out in Denmark. Within Acoustics in particular, DFM co-operates with Brüel & Kjær A/S the Danish Primary Laboratory of Acoustics. Additionally, DFM has a close collaboration with the Acoustic Technology Group of the Electrical Engineering Department of DTU. Such a collaboration grants DFM access to a valuable academic environment and unique experimental facilities, which helps DFM to carry out scientific research at the highest levels.

Acoustics is one of the four high priority areas for the Danish industry, and DFM Acoustics staff conducts research related to the establishment of the unit of sound pressure in air. DFM's research on Acoustics is heavily oriented to developing primary and secondary methods for the determination of the sensitivity of measurement microphones under free-field, pressure and diffuse-field conditions. Research on the establishment of the unit of sound pressure in air has also lead to investigate novel methodologies for measuring sound with light using laser refractometry techniques based on the measurement of the acousto-optic effect. Another area of interest is the characterisation of acoustic couplers used for the assessment of audiometric instrumentation. The synergy between our core capability and the goals of the EARS project makes DFM the ideal partner to lead WP2, as well as a key contributor in WP5.



DFM
Danish National Metrology Institute

Visit DFM at http://www.dfm.dk

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