

## Short Report on AUV Activities at TÜBİTAK Ulusal Metroloji Enstitüsü

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### Organization

TÜBİTAK Ulusal Metroloji Enstitüsü (UME) is the national metrology institute and the highest technical authority in Turkey for the field of metrology. The work of TÜBİTAK UME is committed to excellence in measurement and testing for the benefit of industries and consumers alike. TÜBİTAK UME operates as national reference laboratory in metrology under the auspices of the Scientific and Technological Research Council of Turkey (TÜBİTAK) placed under the Ministry of Science, Industry and Technology. It meets the requirements for calibration and testing laboratories as defined in the ISO/IEC 17025 standard employing a staff of 263 people (September 2017). It is a fundamental task of TÜBİTAK UME to realize and maintain the standards of the measurement units in compliance with the International System of Units (SI) and to disseminate them, above all within the framework of legal and industrial metrology as well as persuading its scientific and technological development in order to anticipate new measurement and testing requirements in the areas of energy, safety, health, quality and environmental protection. TÜBİTAK UME provides government authorities and key economic players with the technical assistance they require to draft new regulations and standards at national level.

In the overall, TÜBİTAK UME has 27 operational laboratories. Activities in the field of acoustics, ultrasound and vibration (AUV) metrology are carried out by two laboratories: Acoustics Laboratory and Medical Metrology Laboratory. Acoustics Laboratory has three different working areas, namely, acoustics, vibration and gravimetry. Ultrasound filed is covered by activities of Medical Metrology Laboratory. Acoustics Laboratory mainly performs primary and secondary calibration of devices used for acoustical and vibration measurements, e.g. microphones, sound level calibrators, accelerometers, calibration exciters etc. In addition, laboratory provides testing services such as sound power, sound intensity and sound absorption measurements. Acoustical tests (mainly sound power measurements) are performed in full compliance with relevant international standards and are accredited by Turkish Accreditation Agency (TÜRKAK), signatory of the ILAC MRA. Activities in the field of underwater acoustics are not covered by TÜBİTAK UME, but Underwater Acoustics Laboratory of Material Institute under Marmara Research Center is responsible for this field. The Laboratory is Designated Institute in this field since 2012.

### National standards

Being responsible for realization, maintenance and dissemination of units TÜBİTAK UME has

following calibration and measurement set-ups in the AUV field:

- Pressure reciprocity calibration of laboratory standard microphones from 10 Hz to 25 kHz
- Measurement of ultrasound power between 10 mW and 150 W
- Primary calibration of accelerometers with sinusoidal excitation in the range from 10 Hz to 10 kHz in both, magnitude and phase of the complex sensitivity

In addition, TÜBİTAK UME has various calibration set-ups. Some of them are listed below:

- Calibration of sound level meters
- Calibration of sound calibrators and pistonphones
- Calibration and testing of mechanical couplers
- Calibration of vibration measuring chains
- Testing of acoustic couplers and ear simulators
- Calibration of impedance heads

and capability for verification of free-field and diffuse field environments.

Work on the establishment of capabilities for secondary shock calibrations is currently in progress.

### **Infrastructure**

The laboratory is well equipped by various commercially available system and devices. However, there are few systems designed and constructed at TÜBİTAK UME, e.g. laser pistonphone, various reference sound sources, ultrasonic power transducers. TÜBİTAK UME has special acoustical facilities, Full Anechoic Room with 50 Hz cut-off frequency and Reverberation Room with 100 Hz cut-off frequency. These facilities used both for calibration/testing and research purposes.

### **Staff**

In spite of the fact that activity of Acoustics and Medical Metrology Laboratories covers many subject fields there were permanent shortcoming with staff. From 4 to 5 people were working in the AUV field for a long time. This brought limitation to scope of activities with careful investigation of priorities. However the situation was improved a little bit and new staff was hired both for Acoustics Laboratory and Medical Metrology Laboratory. Currently overall number of people working in two laboratories is 9, and four of them are chief researchers. Furthermore three out of 9 people have PhD degree. Work experience of the senior staff in the field of AUV metrology is more than 20 years.

### **Calibration/ Testing Services**

Calibration and measurement capabilities of TÜBİTAK UME in AUV field as published on the BIPM KCDB includes 25 entries with the following breakdown in the subject fields: 16 in sound in air, single entry in ultrasound, and 8 entries in the field of mechanical vibration. No changes in CMCs were made during reporting period. However TÜBİTAK UME is planning to revise CMC entries significantly on the base of results of CCAUV.U-K3 and EURAMET.AUV.A-K5 comparisons in the nearest future.

On the average TÜBİTAK UME annually performs about 300 calibrations in AUV field for customers. The great majority of these calibrations are calibrations of microphones, sound calibrators, sound level meters, accelerometers and vibration measuring devices. The number of calibration certificates issued in the field of ultrasound is very limited. However TÜBİTAK UME is strongly involved in research work in this field, especially on subjects related to characterization of HIFU transducers, development of transducers and devices for ultrasound power measurements. As five accredited calibration laboratories became operational in Turkey during past ten years, slight decrease in the number of calibrations performed by TÜBİTAK UME for customers occurred. These laboratories are accredited mainly for calibration of sound level meters, sound calibrators, accelerometers and noise dose meters.

## Comparisons

BIPM Key Comparisons Database (KCDB) has records on 9 key comparisons participated by TÜBİTAK UME in AUV field. 3 other bilateral comparisons conducted with PTB (Germany) at the earliest stage of the establishment of Acoustics Laboratory are not registered at the BIPM KCDB, but their results are publicly available (e.g. Final Report of the EUROMET Project No: 736).

There were two official comparisons with TÜBİTAK UME involvement in the period from 2015 to 2017. They are following:

### **EURAMET.AUV.A-K5**, Comparison of laboratory standard microphone calibrations

TÜBİTAK UME performed calibrations of microphones in the frequency range from 10 Hz to 10 kHz in February 2014 and reported results to pilot laboratory. Draft B of the comparison is under preparation.

### **COOMET.AUV.V-K1**, Comparison of accelerometer calibrations

Although measurements within the comparison were completed in 2008, no consensus was reached on the comparison report. This was mainly due to disagreement between participants on the linking of the results to the results of CCAUV.V-K1 comparison. Pilot laboratory, VNIIM (Russia) produced the revised version of the Draft B, which was distributed to participants and agreed by them. The comparison report is under consideration of the CCAUV KCWG.

In addition, two bilateral comparisons were carried out in the framework of cooperation between TÜBİTAK UME and National Metrology Institute of the Kingdom of Saudi Arabia (SASO NMCC).

The scope of the comparisons covers:

- Calibration of LS1p and LS2p microphones by the pressure reciprocity method in the frequency range 10 Hz - 10 kHz and 10 Hz - 25 kHz for LS1p and LS2p microphones respectively.
- Calibration of reference standard accelerometers (single ended and back-to-back) by laser interferometry in the frequency range from 10 Hz to 10 kHz

It is worth to mention that TÜBİTAK UME will be piloting comparison on calibration of sound level meters in accordance with IEC 61672-3 standard. This comparison is an initiative of European Accreditation Cooperation (EA) and will involve accredited laboratories all over the Europe. It is planned to start comparison in the first quarter on 2018.

## **Research and Other Projects**

Since the establishment of basic calibration capabilities at the very beginning up to the recent years, TÜBİTAK UME has placed a growing emphasis on research activities that cross into areas that are outside its traditional remit as a national metrology institute. In AUV field TÜBİTAK has completed successfully or is currently active in the projects, which brief summary outlined below:

### **Metrology for a universal ear simulator and the perception of non-audible sound (Ears)**

TÜBİTAK UME was involved in the tasks of characterization of novel universal ear simulator, which has the potential to significantly improve the calibration of audiological devices for better diagnosis and screening results mainly for newborns and children. The institute together with other partners performed measurements of transfer impedance of the universal ear simulator prototype. In addition, investigation of dependence of universal ear simulator on environmental conditions like static pressure and temperature were carried out. Furthermore, TÜBİTAK UME made clinical trials of universal ear simulator prototypes. The project was completed successfully in 2015.

### **Dosimetry for Ultrasound Therapy (DUTy)**

The aim of the joint research project under European Metrology Research Programme (EMRP) was to develop the metrological infrastructure (definitions, validated measurement and modeling methods) which would underpin the specification of dose for therapeutic ultrasound applications allowing appropriate treatment planning and risk assessment. TÜBİTAK UME's activity was focused on the development of laboratory standards for thermal and non-thermal therapeutic dose parameters. TÜBİTAK UME worked on quantitative assessment of thermal and mechanical effects of therapeutic ultrasound by sonicating a joint-mimicking phantom, made of muscle-equivalent material. The project was completed in 2015.

### **Realisation, dissemination and application of the unit watt in airborne sound (SIB56 SoundPwr)**

The project, which is currently in progress, has the primary goal to establish traceability for the measurand sound power to SI units. Starting point is a primary standard for the unit Watt in airborne sound. TÜBİTAK UME among other four partners developed a primary standard for airborne sound power in the frequency range between 100 Hz and 20 kHz based on a vibrating solid body. Sound power of the source was determined on the base of velocity values measured by laser vibrometer and by conventional methods. Results for both methods are in agreement in the order of 0.5 dB for the broad frequency range with exceptions at low frequencies below 125 Hz. The joint research project has been completed successfully in 2016.

### **Metrology for modern hearing assessment and protecting public health from emerging noise sources (Ears II)**

The joint research project in the framework of the European Metrology Programme for Innovation and Research (EMPIR) has been started in 2016. The project is considered somehow as a continuation of the Ears project. There are many ambitious goals of the project involving 11 partners from 6 European countries, where PTB (Germany) acts as a coordinator. Partners will investigate how infrasound and ultrasound affect human beings. Different means with methods of audiology and imaging procedures of neurology will be applied by partners. Interest will

particularly be focussed on the measurement and assessment of airborne ultrasound at workplaces. This includes also the development of new hardware which is additionally granted by another project. Furthermore the development of a novel universal ear simulator (family of devices) will be continued and finished. In connection with a newly developed calibration procedure for transient signal it has the potential to significantly improve the calibration of audiological devices for better diagnosis and screening results mainly for newborns and children. The project is currently in progress. TÜBİTAK UME is involved in activities of four workpackages out of 7.

### **Development of Metrology Infrastructure at SASO (Saudi Arabia)**

TÜBİTAK UME is involved in the joint project with Standardization Organization of Kingdom of Saudi Arabia (SASO) with the aim of establishment metrological infrastructure at the National Measurement and Calibration Center (NMCC). In the AUV field this activity mainly involves the following calibration systems:

- System for reciprocity calibration of microphones
- System for comparison calibration of microphones
- System for calibration of sound level meters and sound calibrators
- System for calibration of audiometers
- System for primary and secondary calibration of vibration pick-ups, calibration exciters and vibration measuring chains.

All systems were successfully designed, purchased and installed at SASO NMCC. Extensive training of SASO NMCC both at TÜBİTAK UME and SASO has been done. The project is expected to finish by the end of 2017.

### **Renovation and Further Development of TÜBİTAK UME Research Infrastructure**

3 years investment project has been started in May 2017 and is funded by Ministry of development of Turkish Republic. Although the core part of the project deals with an establishment of infrastructure for quantum metrology, the project itself consists of 22 workpackages. 3 of them are concerning with establishment of new infrastructure for acoustics and vibration measurements. This includes extension of frequency range for primary microphone calibrations (both magnitude and phase) down to 1 Hz, extension of frequency range of primary calibration of vibration pick-ups down to 0,5 Hz and establishment of system for shock calibrations.

### **Publications**

The list of publications of TÜBİTAK UME in AUV field in the period from 2015 to 2017 is given below:

#### **Sound in air**

1. E.Bilgiç, G.Gülmez, S.Özen, V.Senay, S.Pat, S.Korkmaz, R.Mohammadigharehbagh, **Investigation of the Thickness Effect to Impedance Analysis Results Algan Acoustic Sensor**, In Proceedings of the 9th International Physics Conference of the Balkan Physical Union, 24-27 August 2015, İstanbul, Turkey
2. S.Pat, S.Özen, E.Bilgiç, G.Gülmez, V.Senay, S.Korkmaz, R.Mohammadigharehbagh, **Impedance Analysis of Nano Thickness Layered Algan Acoustic Sensor Deposited by**

- Thermionic Vacuum Arc**, In Proceedings of the 9th International Physics Conference of the Balkan Physical Union, 24-27 August 2015, İstanbul, Turkey
3. B.Karaböce, E.Bilgiç, E.Sadıkoğlu, C.Kırbaş, H.O.Durmuş, **Characterization of New Design Ear Simulator To Be Used in Newborn Hearing Tests**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
  4. B.Karaböce, H.O.Durmuş, **System Established at TÜBİTAK UME for Hearing Aids Test and Measurement Results**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
  5. C.Kırbaş, E.Bilgiç, E.Sadıkoğlu, **The Effect of Near Field on the Determination of Sound Power Level**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
  6. E.Bilgiç, C.Kırbaş, E.Sadıkoğlu, H.Mutaf, **Influence of Measurement Surface and Number of Microphones on Determination of Sound Power Level of Noise Sources**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
  7. C.Kırbaş, E.Bilgiç, E.Sadıkoğlu, **Research on a Realization of the Unit “Watt” in Airborne Acouscis**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
  8. K. Saher, B.Karaböce, **Auralizations of Monosyllabic Word Lists For Hearing Impaired Students - A Preliminary Study**, In Proceedings of the 9th Iberian Congress and the 47th Spanish Congress on Acoustics (EuroRegio2016), 13-15 June 2016, Porto, Portugal
  9. S.Brezas, P.Cellard, H.Andersson, C.Guglielmone, C.Kırbaş, **Dissemination of the Unit Watt in Airborne Sound: Aerodynamic Reference Sound Sources as Transfer Standards**, In Proceeding of the 45th International Congress and Exposition on Noise Control Engineering (Inter-Noise 2016), 21-24 August 2016, Hamburg, Germany
  10. C.Kırbaş, H.Andersson, C.Guglielmone, V.Wittstock, E.Bilgiç, **Primary Sound Power Sources for the Realisation of the Unit Watt in Airborne Sound**, In Proceeding of the 45th International Congress and Exposition on Noise Control Engineering (Inter-Noise 2016), 21-24 August 2016, Hamburg, Germany
  11. C.Guglielmone, V.Wittstock, C.Kırbaş, H.Andersson, **Main Achievements of the EMRP Sound Power Project and Future Prospects**, In Proceeding of the 45th International Congress and Exposition on Noise Control Engineering (Inter-Noise 2016), 21-24 August 2016, Hamburg, Germany
  12. K.Saher, K., S.Nas, B.Karaböce, C.Kırbaş, E.Bilgiç, **Room Acoustic Modelling of a Reverberation Chamber**, In Proceeding of the 45th International Congress and Exposition on Noise Control Engineering (Inter-Noise 2016), 21-24 August 2016, Hamburg, Germany
  13. R.Barham, E.S.Olsen, D.Rodrigues, S.Barrera-Figueroa, E.Sadıkoğlu, B.Karaböce, **The Calibration of a Prototype Occluded Ear Simulator Designed for Neonatal Hearing Assessment Applications**, Journal of Acoustical Society of America, 140:2 (2016), pp. 806-813
  14. E.Bilgiç, H.Mutaf, C.Kırbaş, E.Sadıkoğlu, **Evaluation of Uncertainty Contributions of Measurement Surface and Number of Microphone Positions in Determination of Sound Power Levels**, In Proceedings of International Conference on Computational and Experimental Science and Engineering (ICCESEN 2016), 19 – 24 October 2016, Antalya, Turkey

15. B.Karaböce, E.Sadıkoğlu, E.Bilgiç, **Characterization and Clinical Trials of the Prototype Ear Simulator Designed for Neonates Hearing Assessment**, Acoustics Australia, 3:7 (2017), pp.1-8

## Ultrasound

1. B.Karaböce, **Focused Ultrasound Temperature Effect in Tissue-mimicking Material and Sheep Liver**, In Proceedings of IEEE International Symposium on Medical Measurements and Application (MEMEA), 7-9 May 2015, Torino, Italy
2. B.Karaböce, H.O.Durmuş, **Investigation of Thermal Effect In Vitro Liver and Lung Induced by a HIFU Transducer**, In Proceedings of National Congress of Medical Technologies (TIPTEKNO'15), pp.519-522, 15-18 October 2015, Bodrum, Turkey (In Turkish)
3. B.Karaböce, A.Şahin, A.T.İnce, Y.Skarlatos, **Characterization of Pressure Fields of Focused Transducers at TÜBTAK UME**, Physics Procedia 70 (2015), pp.1241-1245
4. B.Karaböce, H.O.Durmuş, **Visual Investigation of Heating Effect in Liver and Lung Induced by a HIFU Transducer**, Physics Procedia 70 (2015), pp.1225-1228
5. G.Durando, C.Guglielmone, J.Haller, O.Georg, A.Shaw, E.Martin, B.Karaböce, **Towards Comparison of Ultrasound Dose Measurements - Current Capabilities and Open Challenges**, Physics Procedia 70 (2015), pp.1114-1118
6. B.Karaböce, K.Kılıç, G.Erdoğan, **Investigation of Ultrasonic Fields Produced by HIFU Transducers Used in Cancer Therapy**, In Proceedings of 2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 15-18 May 2016, Benevento, Italy
7. B.Karaböce, D.Kaleci, A.Şahin, **Experiential Investigation of Nonlinear Acoustic Field Structure in Two and Three Dimensions**, In Proceedings of 2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 15-18 May 2016, Benevento, Italy
8. B. Karaböce, E.Çetin, H.O.Durmuş, **Investigation of Temperature Rise in Tissue Mimicking Material Induced by a HIFU Transducer**, In Proceedings of 2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 15-18 May 2016, Benevento, Italy
9. B.Karaböce, M.Özdingiş, H.O.Durmuş, E.Çetin, **Portable Ultrasonic Wattmeter For Ultrasonic Probe Calibration**, In Proceedings of National Congress of Medical Technologies (TIPTEKNO'16), 27-29 October 2016, Antalya, Turkey (In Turkish)
10. B.Karaböce, E.Çetin, H.O.Durmuş, M.Özdingiş, **Investigation of the Temperature Effect of Ultrasound Used in Cancer Therapy**, In Proceedings of National Congress of Medical Technologies (TIPTEKNO'16), 27-29 October 2016, Antalya, Turkey (In Turkish)
11. B.Karaböce, **Investigation of Thermal Effect by Focused Ultrasound in Cancer Treatment**, IEEE Instrumentation & Measurement Magazine, 19:5 (2016) : pp. 20-25
12. M.Y.Seyitsoy, R.A.Suleymanov, A.P.Odrinsky, C.Kırbaş, **Effect of Deep Native Defects on Ultrasound Propagation in TlInS<sub>2</sub> Layered Crystal**, Physica B Condensed Matter, 497(2016), pp. 86-92
13. B.Karaböce, E.Çetin, H.O.Durmuş, M.Özdingiş, H.Korkmaz, J.Altun, S.Argun, **Experimental Investigations of Viscous Heating Effect of Thermocouples under Focused Ultrasound Applications**, In Proceedings of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 7-10 May 2017, Minnesota, USA

14. B.Karaböce, H.O.Durmuş, E.Çetin, M.Özdingiş, **Calibration of Therapeutic Ultrasonic Transducers with the Modified Radiation Force Balance System**, In Proceedings of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 7-10 May 2017, Minnesota, USA

### **Vibration and Acceleration**

1. E.Bilgiç, Y.Durgut, **Effect of Waveform Model on Sensitivity Values of Transducers Used in Dynamic Mechanical Measurements**, Acta Physica Polonica A, vol:128(2), pp.267-270, August 2015
2. E.Bilgiç, E.Sadıkoğlu, C.Kırbaş, **The Measurement and Evaluation of Vibration: Exposure to Hand-arm and Whole-body Vibration**, In Proceedings of the 11th National Acoustical Congress, İstanbul Technical University, 19-20 October 2015, İstanbul, Turkey (in Turkish)
3. E.Bilgiç, **Determination of Pulse Width and Pulse Amplitude Characteristics of Materials Used in Pendulum Type Shock Calibration Device**, In Proceedings of International Conference on Computational and Experimental Science and Engineering (ICCESEN 2016), 19 – 24 October 2016, Antalya, Turkey
4. E.Bilgiç, F.A.Alsubaey, İ.Aladhyani, E.Sadıkoğlu, C.Kırbaş, **Current Situation in Vibration Field at NMCC and Calibration of Signal Conditioner**, In Proceedings of IMEKO 23rd TC3, 13th TC5 and 4th TC22 International Conference, 30 May – 1 June 2017, Helsinki, Finland