Know-How Transfer on Acoustic Imaging

(April - September 2015)

1. Companies, whose employees participated in discussions about applications of the Smart Lab Acoustic Camera:

(i) ***Dundee Precious Metals Inc***. www.dundeeprecious.com
The Canadian-based, international mining company is engaged in the acquisition, exploration, development, mining, and processing of precious metal properties. Its business objectives are to identify, acquire, finance, develop and operate low-cost, long-life mining properties. In Bulgaria the company is mining in village of Chelopech and in Krumovgrad. The contract of gold/copper underground mine in village of Chelopech is to 2025. Gold production in 2013 is estimated of around 4 t. Ground-based equipment of the mine generates unwanted *amount* of acoustic noise. The Acoustic Camera is suitable for noise source localization and noise characterization. The obtained data may be used for the noise suppression via acoustic cloaking or other approaches.

(ii) Bearings manufacturing companies:
SKF Bearings Bulgaria EAD and the ***Timken Company, Romania***. The latter uses to purchase complete testing tools from internationally recognized companies. The standard bearing testing approach requires the bearing to be placed into the special device and measured by vibration signals processing. The Acoustic Camera enables non-contact acquisition of acoustic signals, emitted by the bearing under analysis. The health-monitoring tasks may be resolved on place, in industrial conditions, without dismounting.

(iii) ***AtomToploProekt OOD***. www.atomtoploproekt.com
Non-contact acquisition of acoustic emissions of equipment of power plants in Bulgaria may be used for health monitoring and non-destructive testing tasks.

(iv) **Chemical plants Devnia**. There is a proposal to estimate the reason of enormous noise in a newly built chemical installation.

2. Foreign institutions, which may have interest to AComIn outcomes in new algorithms for the Smart Lab Acoustic Camera:

(i) ***Danish company: Brüel & Kjær*** (Sound and Vibration Measurement A/S) www.bksv.com

The newly developed signal processing algorithms on noise source identification were briefly presented to Innovation group of the company at a training course on "Acoustic Imaging & Noise Source Identification" at 29 April 2015.

(ii) ***Pratt School of Engineering - Duke University*** (USA) www.pratt.duke.edu
Experimental results on Capon-based angular resolution improvement were shared to participants of "XXVII Edition of the Distributed Doctoral School on Metamaterials", held in "Roma Tre" University, Rome, Italy with poster presentation at 07 May 2015. Discussions with following participants of the school showed opportunity to apply Acoustic Camera for testing of newly developed acoustic cloaks and lenses: Rasmus E. Christiansen, Technical University of Denmark, Denmark and Prof., Ph.D. Steven A. Cummer, Duke University, USA.

(iii) ***JRC, Ispra Italy***. A meeting was organized with the team of the Institute for the Protection and Security of the Citizen in Joint Research Center. Dr. Dario Tarchi, the team leader was acquainted with the last achievement of the staff of MMSIP Department and he expresses particular interest to the enhanced resolution of acoustic camera. Another participant in the meeting was Prof. Cantoni from Pavia University. Bulgarian presentation was prepared by Dimo Dimov and Kiril Alexiev .

3. Bulgarian education institutions who are interested in further application of Smart Lab Acoustic Camera:

(i) ***Technical University of Sofia***:

a. *Vice rector, Prof. PhD Ivan Kralov*. Acoustic camera was presented to scientific staff of his Laboratory of vibration and noise in machines. Professor has interest in noise reduction of railway transport. Acoustic Camera may be applied for acoustic imaging for noise source localization and diagnosis of passing railway carriages.

b. *Faculty of Transport - Assoc. Prof. PhD Plamen Petrov*. Acoustic camera was presented to scientific staff of Air transport Department. Opportunity to provide acoustic diagnostics of internal combustion engines and helicopter engines at helicopter repair factory were considered.

c. Acoustic camera was presented to scientific and student staff of *Mechanical engineering Department*. A joint research work on non-contact acoustic diagnostics of ball bearings is initiated with Assist. Prof. Ph.D. Vladislav V. Ivanov in SKF Laboratory at TU - Sofia. We carried out first measurement session on acoustic diagnostics of the bearings at **13.05.2015**. The obtained results will be published [9]. The results may be interesting to bearings manufacturing company SKF Bearings Bulgaria EAD.

d. Possibility to apply the Acoustic Camera for acoustic noise suppression of home heating systems was considered with Prof. Todorov. Some test measurements were carried out over experimental heating system. The talks are in progress.

(ii) ***The High College of Telecommunications and Post - Sofia***. Cooperation on development and testing of new beamforming techniques may be organized with Assoc. Prof. DSc Peter S. Apostolov.

4. Signed agreements for joint work with international partners

Several agreements between Mathematical Methods for Sensor Information Processing Department of Institute of Information and Communication Technologies at Bulgarian Academy of Sciences and other organizations were signed in 2015 in order to enable joint work on the problems of passive systems with experts on noise radar technology, aperture synthesis and adaptive signal processing. Our partners in these agreements of understanding are the following non-profit organizations from Kharkiv, Ukraine:

(i) Laboratory for Nonlinear Dynamics of Electronic Systems, O.Ya. Usikov Institute for Radiophysics and Electronics, National Academy of Sciences of Ukraine. The Institute address is 12, Proskura St., Kharkov, Ukraine. Contact: *Prof. K. Lukin*.

(ii) Research and Development Center of Integrated Informational Radio Electronic Systems and Technologies, Kharkiv National University of Radio Electronics, Ministry of Education and Science of Ukraine. The University address is 14, Lenin Ave, Kharkov, Ukraine. Contact: *Prof. D. Lekhovytskiy*.

(iii) Department of Aircrafts Radio Electronic Systems Design, Faculty of Aircrafts Radio Engineering Systems, National Aerospace University “KhAI”, Ministry of Education and Science of Ukraine. The University address is 17, Chkalova St., Kharkiv, Ukraine. Contact: *Doc. V. Pavlikov*.

5. Achieved Improvement of the technical specifications of Acoustic Camera:

(i) Modification of Acoustic Camera microphone array.

(ii) Generation of 4D acoustic images.

(iii) Further enhancement of range resolution of the Acoustic Camera using correlation of incoming acoustic signals. Technically it will be obtained using both beamforming and bistatic reception.

(iv) Comparison of the performance on the Fourier NAH with the interpolated signal and a signal from a real rearranged regular aperture is planned to be done.

(v) Further improvement of the direction-of-arrival estimate can be achieved by using new methods for a frequency estimation and using multiple channels/segments of data. It will be shown that autoregressive moving averaged model based method has a big advantage over a autoregressive model based method known as modified covariance one.

6. Searching for new partners from the industry and others areas for implementation of acoustic camera like:

(i) Liebherr refrigerator plant

(ii) Sofia municipality