Institution: Loughborough University

Unit of Assessment: B9 Physics

Title of case study: Improvements to the Environment by means of Broad Band Sound Attenuating Devices

1. Summary of the impact

Sound pollution, which harms ***quality of life*** and ***health*** (e.g. hearing loss, hypertension and heart disease), is a subject of public concern and legislation. Research at Loughborough University has led to the design and production of ***a new generation of sound barrier*** for a wide range of industrial and business partners, a number of them leaders in their field. These sound barriers provide improved ***environmental benefit*** and ***reduced cost*** in ***compliance with EU Regulations*****.** A ***spin-out*** company (Sonobex) has been established to test and market these designs and products. Outreach by Sonobex through the media and at the Houses of Commons has led to a contribution to the ***understanding of science and engineering*** to both the ***public*** and to ***policy makers***.

Image: Drs Chalmers and Elford with the first commercial prototype.

2. Underpinning research (indicative maximum 500 words)

Noise barriers are used to reduce noise disturbance from industrial plant, roads, railways etc. Traditionally outdoor noise barriers are constructed from solid structures (concrete walls etc.) which act both to absorb the sound and also, by reflection, to deflect it away from the areas that require protection. Whilst these traditional methods can be very effective they generally suffer from the major disadvantage of preventing the free flow of air and light through the barrier. Recent years have seen a growing interest in the potential for use of sonic crystals – arrays of cylindrical rods - as noise barriers. An advantage of sonic crystals (SCs) is that by varying the distance between the rods it is possible to attain peaks of attenuation in a selected range of frequencies.

A further advantage of an SC barrier in comparison to more traditional sound barriers are its ability to allow light to pass and, uniquely, that it does not present an obstruction to the free flow of air. However, barriers using 'conventional' SCs suffer from the major disadvantage of providing attenuation only over a rather narrow frequency band (and harmonics thereof) and are therefore unsuitable as barriers to broad band sound.

The concept of using Locally Resonant Sonic Crystals (LRSC) in which the cylinders in the array act individually as resonators whose frequency differs from that of the array helps to alleviate this problem but broad band attenuation is still not achieved. Experimental and modelling work carried out in the Loughborough University Physics Department by research students and latterly postdoctoral researchers Dan Elford and Luke Chalmers (2007-2013) under the joint supervision of Prof. Kusmartsev (Head of Department, staff member 1990 to date) and Dr. Swallowe (Senior Lecturer, staff member 1984 to date) **[3.1, 3.2]** in which the use of multiple active Helmholtz resonators as scattering elements was investigated has shown that carefully designed LRSCs can provide attenuation well in excess of that provided by normal 'mass law' attenuators and in broader frequency ranges than conventional LRSCs.

The key aspects of the research outcomes and the potential impact are that with LRSC systems attenuation is as good as with conventional barriers but

1) In all situations a flow of air and light is possible – thus systems such as industrial compressors can be acoustically shielded without being enclosed. This is a major advantage since air flow is required to provide cooling **[3.1, 3.2]**

2) LRSCs can be manufactured from a very wide range of materials and can be used to architecturally enhance the appearance of a building while providing (when used as a window covering) shade from direct sunlight and attenuation of exterior sound along with a free flow of cool air **[3.1, 3.2]**

3) Conventional sound barriers for outdoor use (e.g. along motorways in residential areas) are intermittently subjected to very considerable wind loading resulting in the need for massive supports. The wind permeability of LRSC barriers considerably alleviates this requirement **[3.1, 3.2]**

4) Barriers can attenuate at low acoustic frequencies without the need to satisfy the mass law. **[3.1, 3.2]**

The work is protected by GB and international patents **[3.3, 3.4, 3.5, 3.6]**

3. References to the research (indicative maximum of six references)

Because of the commercial implications journal publications are limited but it is worth noting that the Journal of the Acoustical Society of America is one of the most highly regarded and has the highest 'H-index' of any acoustics journal as well as being rated A* confirming the quality of the underlying research. Since 2010 over £350k has been invested in commercialising the technology.

3.1. **Chalmers, L., Elford, D., Kusmartsev, F. and Swallowe, G.M., Acoustic band gap formation in two-dimensional locally resonant sonic crystals comprised of Helmholtz resonators, *International Journal of Modern Physics B*, 23, 4234-4243 (2009), DOI: 10.1142/S0217979209063390 – B ranked journal in ERA 2010 journal rankings H–index 49**

3.2. **D. Elford, L. Chalmers, F. V. Kusmartsev, and G. M. Swallowe, Matryoshka locally resonant sonic crystal, *Journal of the Acoustical Society of America*, 130(5), 2746-2755 (2011), DOI: 10.1121/1.3643818 – A* ranked journal in ERA 2010 journal rankings. H-index 105**

3.3. GB patent application GB0901982.9 (Feb 2009), *Attenuators, arrangements of attenuators, acoustic barriers and methods for constructing acoustic barriers*; G.M. Swallowe, D. Elford, L. Chalmers, F. Kusmartsev

3.4. International patent application PCT/EP2010/051370 (Feb. 2010); *Attenuators, arrangements of attenuators, acoustic barriers and methods for constructing acoustic barriers*; G.M. Swallowe, D. Elford, L. Chalmers, F. Kusmartsev

3.5. European Patent Application No. 10704128.7 (2012); *Attenuators, arrangements of attenuators, acoustic barriers and methods for constructing acoustic barriers*; G.M. Swallowe, D. Elford, L. Chalmers, F. Kusmartsev

3.6. US patent application No. 13/148020 (2012); *Attenuators, arrangements of attenuators, acoustic barriers and methods for constructing acoustic barriers*; G.M. Swallowe, D. Elford, L. Chalmers, F. Kusmartsev

Research Grants Obtained:

EMDA Innovation Fellowship: PI Dr. G. Swallowe, CI Prof F. Kusmartsev. £15,948 from October 2010 for 8 months "Sound Blocking Technology"

EPSRC EP/I029001/1: PI Prof. F. Kusmartsev, CI Dr. G. Swallowe. Value £167,750 from January 2011 for 12 months "Practical Sound Attenuation using Broad Band Sound Attenuating Devices"

KTA Funding: 1st Feb 2012-30th Sept 2012: Dr D. Elford £61,000 "Novel Noise Barrier Technology"

Royal Academy of Engineering Enterprise Fellowship: Dr D Elford £83,000 from 30th March 2012 for 12 months to turn research into a viable operating spin out company.

4. Details of the impact (indicative maximum 750 words)

We now provide evidence to show that the research findings that we have cited in 3.1 and 3.2 have resulted in two major impacts:

(1) the design and production of a new generation of sound barrier for a wide range of industrial and business partners, a number of them leaders in their field. These sound barriers not only provide commercial and operational benefit for these companies but they additionally provide improved environmental benefit (reduced sound transmission) and reduced cost in compliance with EU Regulations. A spin-out company (Sonobex) has been established to test and market these designs and products

(2) a contribution to the understanding of science and engineering to both the public and to policy makers, via Sonobex.

Impact 1

The outcome from the research is in the commercialisation stage and the research grants listed in section 3 have been awarded in order to develop commercial products based on the academic research carried out in 2007-2012 **[3.1, 3.2].** A ***spin-out company*** Sonobex Ltd. was formed in May 2013 and prototype sound barriers have been successfully tested. The list of project partners given below is evidence that Sonobex Ltd has ***established its visibility*** and is set to realise its potential in both UK and international markets. Because of the damaging effects of noise on ***public health*** and the ***environment***, European Legislation [The European Parliament and The Council of The European Union, Directive 2002/49/18.7.2002.] for noise has required each member state to prepare noise maps of larger towns and cities and to publish action plans that identify noise standards and set out programmes to reduce levels to these standards. The first UK round of noise mapping has been completed (2011) and the second round of noise mapping is taking place. A follow on regulation to the Environment Noise (England) regulations, 2006 will require reductions in noise limits to take effect from 2016. The noise which is predominately of concern is airborne sound and the Loughborough University research and development of air sound barriers with their advantages as outlined in Section 2 has led to interest from a wide variety of major construction firms. As such the solutions provided by Sonobex Ltd, based on the research conducted within the Unit, is contributing to the implementation of ***public policy*** and ***improved public services***.

Current business partners, attracted to the technology because of its potential for improved ***public health*** and ***quality of life***, include:

- Alkane Energy (Methane Extraction – prototype installed) **[5.1]**
- East Midland Trains (prototype installed) **[5.5]**
- British Gypsum (prototype designed) **[5.2]**
- Tarmac Building Products **[5.3]**
- Cherwell District Council design for first ever acoustically designed sheltered housing for autism sufferers **[5.4];** their application for sheltered housing incorporating Sonobex attenuators has ***won the Department of Health Care and Support Specialist Housing Fund design competition*** and ***will commence construction in 2014***.
- A leading European power infrastructure company (non-disclosure agreement in place) have placed an initial order for a trial instillation for power station use in Brazil.
- Colas rail (France) who are evaluating the SonoBex designs with a view to a roll out in the French rail transport infrastructure.

The range of designs and products include:

- Production of enclosures for use around noisy machinery in factories, air conditioning systems, road drills etc.- the Alkane Energy prototype and the “Major Power Infrastructure Company” order are of this type **[5.1, 5.2].**

- Sound barriers for use along motorways and railways with reduced wind loading, improved drainage and visual impact – East Midlands Trains prototype is in this area as are the Colas rail designs **[5.3, 5.5].**
- Prevention of sound barriers forming a physical barrier to small animal movement.
- Bespoke barriers for special needs – Cherwell District Council sheltered housing application **[5.4].**

Impact 2

Loughborough's spin out, Sonobex has featured on national radio (BBC Radio 4's PM show) and newspaper (The Times, Innovation & Growth supplement) as well as in more specialist outlets (The Engineer magazine and a cover article in Innovation & Research Focus). Sonobex and the BBC have agreed production of a feature in the The One Show for 2014. This provides further evidence of an on-going commitment to public engagement. In addition, for his work on sound barrier technology, Elford won a Bronze award from the Parliamentary & Scientific Committee at the Houses of Commons research competition – SET for Britain. **Sonobex** has therefore made a ***contribution to the understanding of science and engineering*** to both the ***public*** and to ***policy makers***.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Full commercial products are not yet available but trials have been successful and we expect that commercial products and consequent full impact on society will take place in late 2013. Support letters from Tarmac, British Gypsum, Lindhurst/Alkene Energy, Cherwell District Council and East Midlands trains have been provided.

The following sources of corroboration can be made available at request:

5.1. Letter from Managing Director, Lindhurst Engineering Ltd. Midland Road, Sutton-in-Ashfield, Notts., NG17 5HG

5.2. Letter from Project Leader, Project Engineering Dept., British Gypsum, East Leake, LE12 6JU

5.3. Letter from Chief Executive Officer, Tarmac Building Products, Tunstead Road, Buxton, SK17 8TG

5.4. Letter from, Delivery Team, Regeneration and Housing, Cherwell District Council, Bodicote House, Bodicote, OX15 4AA

5.5. Manager, East Midlands Trains Etches Park Depot, Deadman's Lane, Derby, DE24 8WE