ABox: Anechoic Boxes

A novel method for evaluating Wireless Acoustic-Sensor Networks

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INTRODUCTION

Wireless Sensor Networks (WSNs)

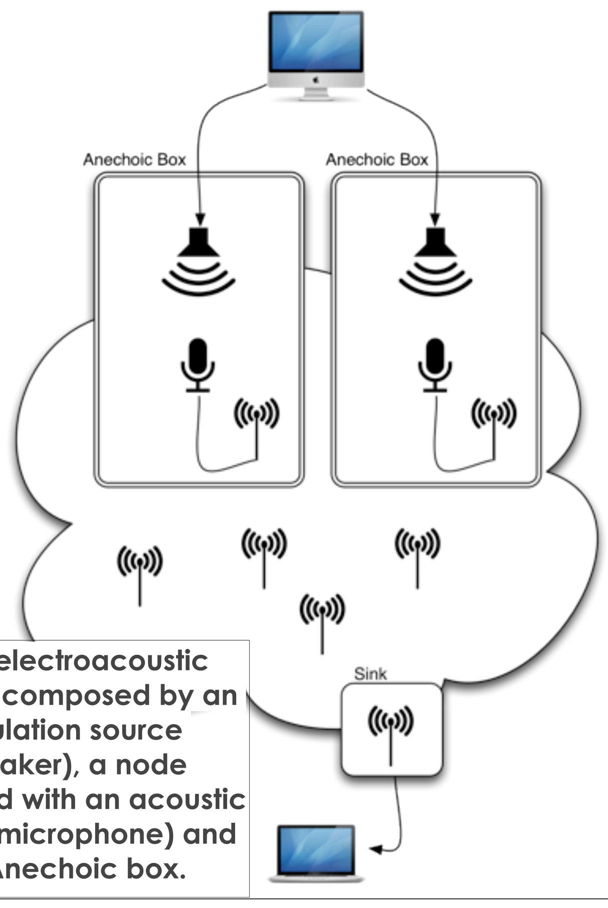
Wireless sensor networks are effective low-cost solutions for real-time data acquisition with flexible scale adaptation [1,2,3,4]. A node is always configured as an independent sampling entity. This kind of network is usually deployed in an area where environmental pollution has an influence on the population, or a nature environment that needs closer research and monitoring. We'll be looking into a specific type of WSN, named acoustic-sensor network for noise monitoring.

Why do we propose this method?

This research proposes a new validation-step for wireless acoustic-sensor networks, where anechoic boxes, constructed using room acoustics technology, will allow making preliminary emulation of the behavior of such networks without the need of in situ try-outs to obtain first impressions. This solution permits multiple parallel tests under different configurations for several applications, using one single system and set-up.

Building an Electro-Acoustic chain for Acoustic WSN evaluation

We need to create a flat electro-acoustic chain, for each individual sensor, that simulates the acoustic information that would normally be registered by the sensor. We want to simulate this independent acoustic open-field condition for each sensor. The small size of sensor nodes allows the implementation of more than one small anechoic box inside the same testing facility, which facilitates the access and allows fast reconfiguration.



Each electroacoustic chain is composed by an emulation source (speaker), a node equipped with an acoustic sensor (microphone) and an Anechoic box.

METHOD

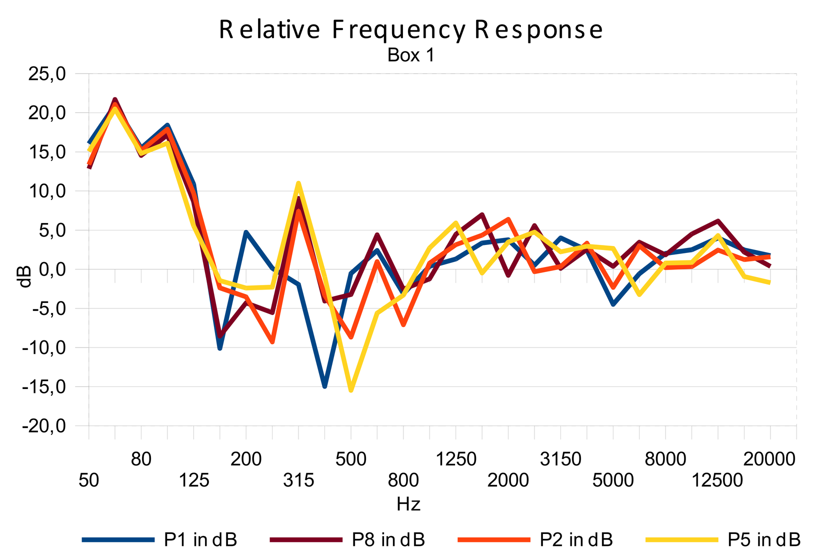
We're offering two different solutions: box 1 was made using modular pieces, making it easier to build; for box 2, we used multilayer-material construction-techniques, which provides better sound insulation. Both boxes were built using materials and components that can easily be found in common hardware stores. There are three important factors to achieve an ideal anechoic environment: a flat sonic-response of the system linked to the environment, the absence of reverberation and a low background noise, achieved by acoustic insulation.

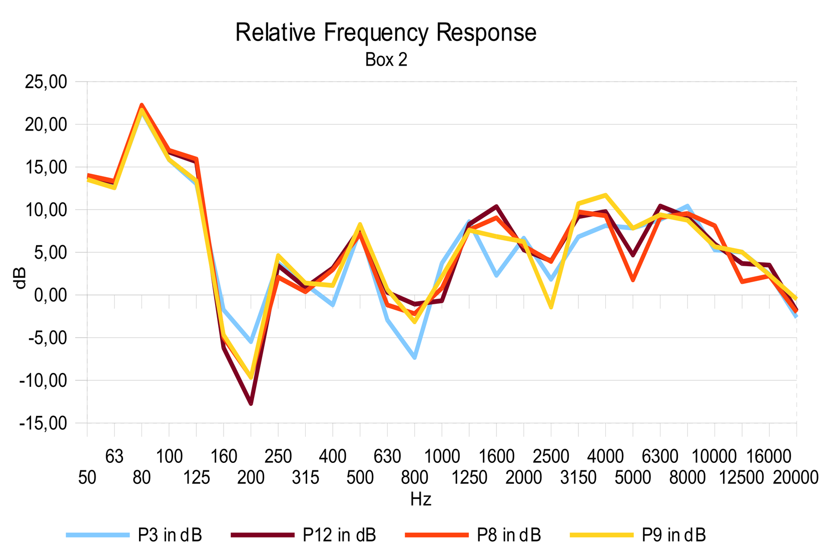
I - Obtaining a flat response of the Electroacoustic chain

Dimensions for the internal volume of the two ABox models (in m, m² and m³), where box 2 follows Bolt's theory		
Box	1	2
Height	0,85	0,6
Width	0,7	0,85
Legth	1	1,15
Net Surface	3,1	3,38
Net Volume	0,6	0,59

Coordinates of the ideal locations inside Box 1 for the acoustic sensor and the source (Origin is most left corner at the door side, looking into the box from outside - in cm)			
Coordinates	X	Y	Z
Ideal Point	36	36	36
Source	38	68	20
Coordinates of the ideal locations inside Box 2 for the acoustic sensor and the source (Origin is most left corner at the door side, looking into the box from outside - in cm)			
Coordinates	X	Y	Z
Ideal Point	45	42	33
Source	46	86	20

If we calculate the height, width and length of a rectangular volume following the relation given by the Bolt's area [5] [7], it is possible to optimize the standard deviation between the spacing of the generated modes. We also need to analyze the audio information received by an acoustic sensor inside our boxes at different points, to define which points interfere less. If we use a flat electroacoustic chain, we can evaluate the frequency behavior of a measured point.

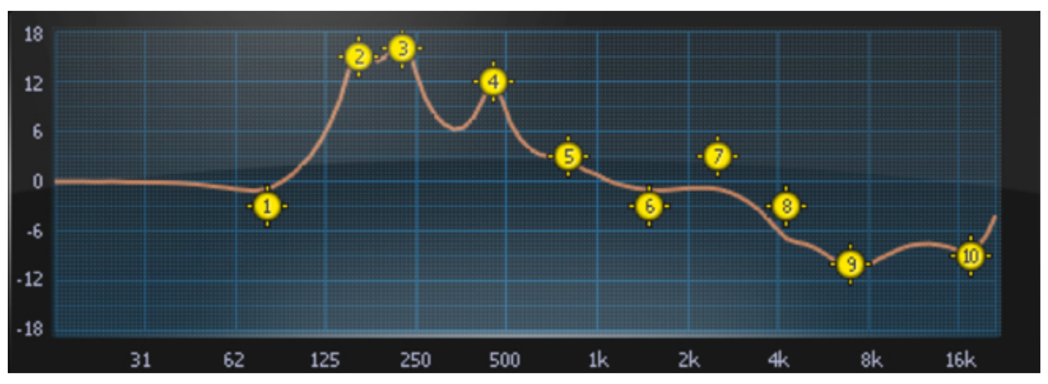


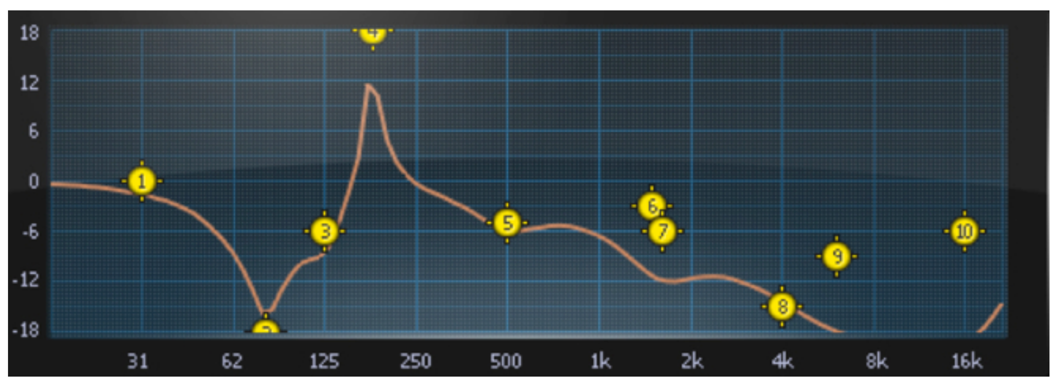


II -Generating the ideal Anechoic Environment

An anechoic performance of the working space is crucial when we need to register the signal as if it was projected in an open-field environment [6]. For this, it's necessary to cover the internal workspace with absorbent foam. This concept works for every frequency with a wavelength four times above the foam thickness [6]. Measurements defined that box 1 has an anechoic-working frequency-range from 200 to 20 Khz, and box 2 from 125 Hz to 20Khz.

To obtain a flat anechoic point of measurement for our system, we propose a one-time equalization process involving all needed compensations.

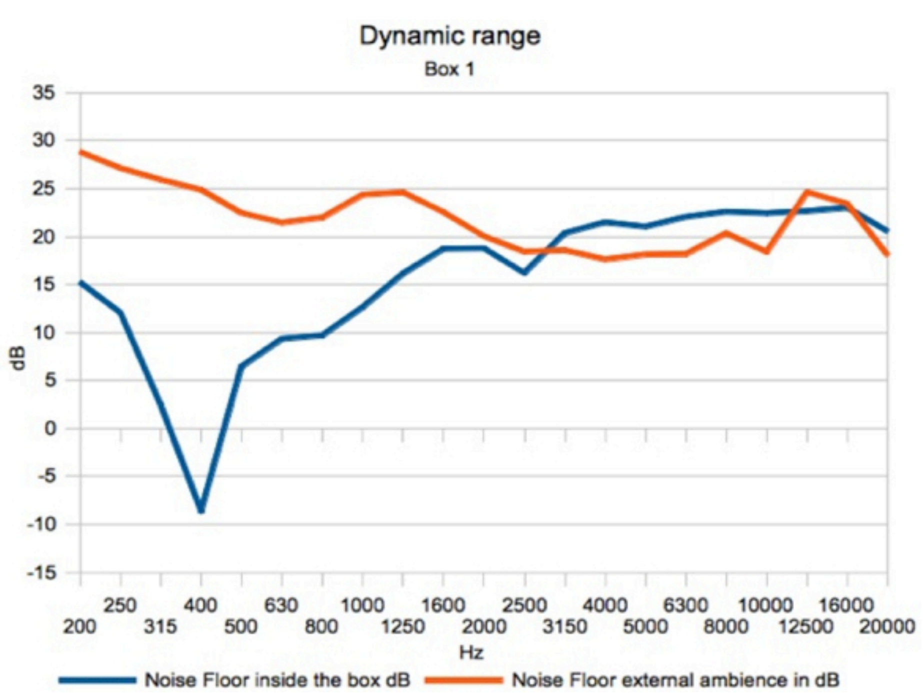


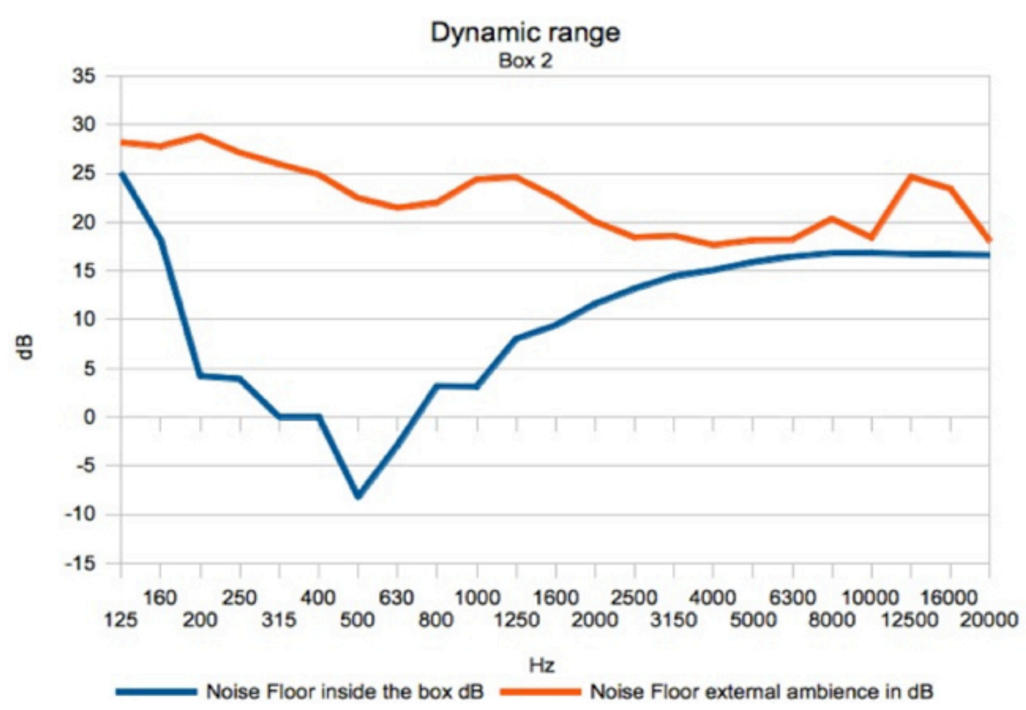


Resultant parametric equalization curves for Box 1(left) and Box 2 (right), to obtain a flat response of the electroacoustic emulation-chain (source: Waves Q10 display).

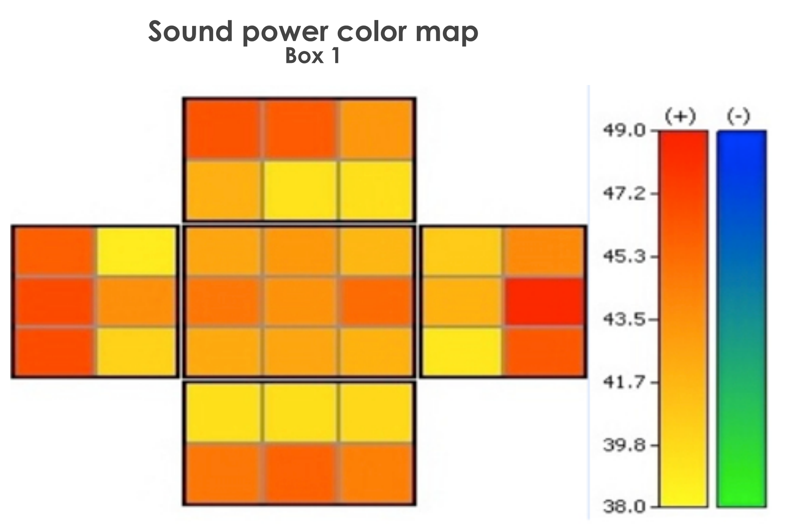
III - Acoustic insulation towards the improvement of the signal to noise ratio

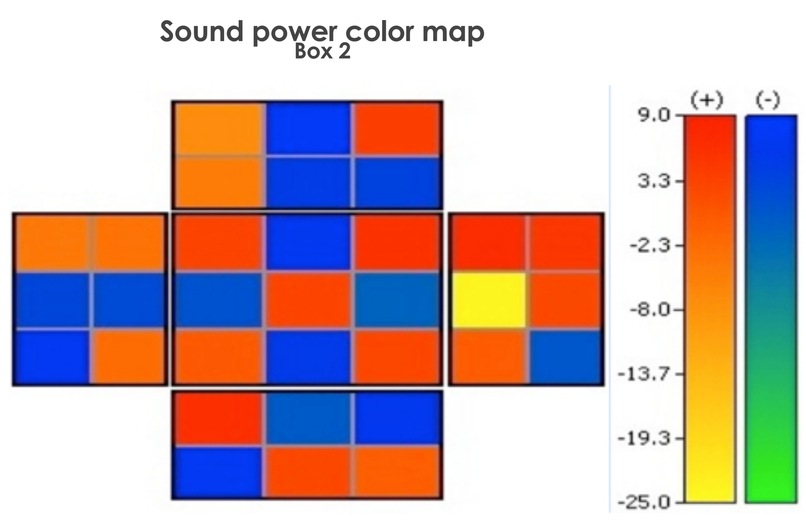
For the structure of Box 1, walls consisting of two glued high-density MDF wooden boards are used: an internal plate with a thickness of 12 mm and an external one with a thickness of 18 mm. For the second box we used a box-in-a-box concept, a mass-air-mass construction system with an air volume in-between the external 18 mm and the internal 12 mm MDF plates, creating two fully detached boxes with separated doors [8,11,12]. We filled the air cavity with absorbent material (rock wool) [9,10].





While at Box 1 (left) most differences between both background noises are around 10 to 15 dB, in the second model (right) most of the readings have differences between 15 and 25 dB.





For the first model (left), the energy comes from the direction of the box and it's clear that most part of the sound is at the bottom of the box. At box 2 (right), for half of the measured points, results aren't able to define if the levels registered are part of the sound source coming from inside the box, or part of the room's background noise.

ABOX 1

ABOX 2

CONCLUSIONS AND FUTURE WORK

Anechoic boxes are quite affordable and fast to build. In our case the materials used for each box had a spending average of 500 euros and the amount of working hours involving 2 persons working together didn't exceed 40 hours, plus another 20 hours (single person) for characterization. Meaning that 2 researchers with access to a Fablab, could implement 3 to 4 units in less than a month.

This method could open doors for several start-ups or small research teams to develop and improve their nodes performance autonomously. With this kind of technology, it's also possible to study different types and qualities of acoustic sensing nodes, microphone capsules and electro-acoustic components in general: All of this inside the same laboratory facility without depending on the schedule of a third parties.

There is still the future possibility of developing an add-on system that permits a fast-reliable adaptation of the entire electro-acoustic chain inside an anechoic box, meaning that the anechoic volume should be able to behave as a perfect open-field without the need of having the microphone always at the same specific measuring point. There is also the opportunity to develop a future study of the polar response of measuring points inside small anechoic boxes, following the growing interest of technologies involving sensor nodes equipped with microphone arrays.

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