Building acoustics measurements: an innovative solution with automatic recognition and optimized workflow

E. Aflalo, S. Bloquet, T. Poli and C. Aujard
ACOEM, 200 Chemin des Ormeaux, 69578 Limonest, France.

Summary
Building acoustics measurements in the field is governed by various sets of measurements and calculation standards for assessing the acoustic performance of buildings. Additional equipment to a sound level meter required to perform measurements (sound sources, tapping machine) usually need additional people to handle them and a remote control mechanism in the sound level meter for triggering the source. Furthermore, the equipment must be moved around the building repeatedly to carry out a measurement campaign. A rigorous field approach and an easy workflow are thus essential in order to conduct a measurement campaign easily and efficiently.
The solution has been designed so that each step eliminates superfluous actions, avoids errors and optimizes work through smart organization of measurements and data storage, automatic identification of each measurement type and on-the-fly calculation of standardized indicators according to various standards, including the new ISO 16283 series, replacing the ISO 140 series.
The purpose of the paper is to present an optimized workflow, with the principle of recognition of the different types of building acoustics measurements as keystone (source room, receiving room, impact noise, background noise, reverberation time measurements). A description of the principle together with the different hypothesis and detection methods used will be outlined.

1. Introduction

This paper presents a complete building acoustics measurements solution whose goals are to simplify the acquisition process and to optimize the measurements organization. It describes in details the automatic measurement types (source, receive, reverberation time interrupted or impulsive, impact noise, background) recognition principles and the measurements organization for an easy and efficient automated on the fly post processing.

2. Recognition principles

2.1 Basics

Real time frequency analysis (1/1 or 1/3 oct) together with time history is used to compare levels over time to specific triggers that allows the system to recognize the type of measurement used.

2.2 Recognition of the measurements in the source room (L1 or reverberation time measurement)

The sound pressure level L1 in the source room is deducted from ISO 3743-2:

$$Lw = L1 - 10\,log\left(\frac{T}{To}\right) + 10\,log\left(\frac{V}{Vo}\right) - 13, \quad (1)$$

In this standard,
Lw: sound power level of the sound source
To = 1 sec; Vo = 1 m3
T: reverberation time of the room
V: volume of the room.

For example classical values in buildings:

- 25<V<75 m3 → 13<10*logV<19
- 0.5<T<2.5 sec → -3<10*logT<4

Knowing the sound power level of the sound source for each 1/N octave band, it is therefore possible to detect the minimum sound pressure level obtained in the source room for L1 measurements:

$$Lw + 4 > L1 > Lw - 9, \quad (2)$$

Example of a sound power spectrum (figure 1) of a sound source; the trigger value must be above the dash line according to equation 2:

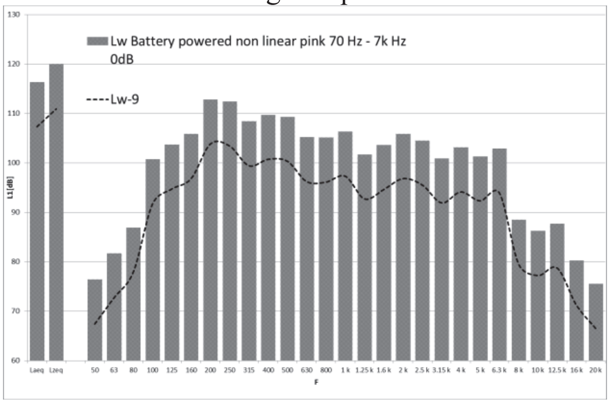

Figure 1: sound power spectrum and trigger limits

To distinguish L1 measurement from interrupted reverberation time measurement, the instrument detects whether the source is on during all the acquisition period or has been switched off during the measurement.

2.3 Recognition of L2 measurements (receiving room)

The sound pressure level in the receiving room L2 is deducted from:

$$L2 = L1 - DnT + 10\log\left(\frac{T}{0.5}\right), \quad (3)$$

Where DnT is the sound insulation value per 1/N octave of the device under test.

Considering usual performance of buildings:
- lowest performance device (DnTMin)
- highest performance device (DnTMax)
- 0.5<T<2.5 sec → 0<10*logT/0.5<7

$$Lw - DnTMax - 9 < L2 < Lw - DnTMin + 11, \quad (4)$$

2.4 Recognition of Li impact noise in the receiving room

The impact sound pressure level Li in the receiving room is deducted from:

$$Li = LnT + 10 * \log\left(\frac{T}{0.5}\right), \quad (5)$$

Considering usual performance of buildings:
- lowest performance device (LnTMax)
- highest performance device (LnTMin)
- 0.5<T<2.5 sec → 0<10*logT/0.5<7

$$LnTMin - 7 < Li < LnTMax, \quad (6)$$

Due to possible interaction between the detection of L2 and Li, it is recommended to make the selection of trigger on Li based on frequencies not excited by the sound source. We recommend to use trigger on the following frequencies: 10 Hz (1/3 oct) or 8 Hz (1/1 oct).

2.5 Recognition of impulsive reverberation time

An impulsive reverberation time measurement is recognized on the LCpk criteria using a trigger value that must be greater than the impulsive noise created by the sound source LCpkMax; from eq. 2 we can deduct:

$$LCpk\ for\ impulse\ RT > LCpkMax + 3, \quad (7)$$

Considering the performance of the sound source (LCpkMax evaluated as Lw + 4), if during a measurement:

$$LCpk > Lw + 7, \quad (8)$$

Then the impulsiveness of the sound is recognized as a measurement for impulsive reverberation time.

2.6 Recognition of background noise measurement

If none of the previous criteria is satisfied, the instrument proposes to classify the measurement as background noise.

3. Example of extrema for the determination of the trigger levels

Various simulations and measurements in dwellings have been collected and the table below gives the summary of the statistical values that have been used to establish the trigger levels for automatic recognition using the loudspeaker characteristics described in figure 1:

F [Hz]	L2 Min	L2 Max	L1 Min	Li Min	LiMax	Li Min
16	-15	13	1	56	80	60
20	4	31	21	55	78	58
25	13	39	31	54	77	57
31,5	31	58	51	53	76	57
40	39	67	61	56	80	56
50	45	73	69	55	78	55
63	46	75	74	54	77	54
80	48	78	80	53	76	53
100	59	88	93	52	75	52
125	59	87	96	48	68	48
160	55	88	98	44	66	44
200	59	90	106	42	66	42
250	56	87	105	36	64	36
315	49	82	101	32	64	32
400	47	81	102	29	64	29
500	44	77	101	26	64	26
630	38	71	98	18	61	18
800	37	70	98	11	60	11
1000	36	69	99	6	56	6
1250	29	63	95	5	52	5
1600	28	65	97	4	47	4
2000	28	67	98	4	42	4
2500	24	69	97	3	40	3
3150	20	67	94	3	36	3
4000	20	66	97	3	34	3
5000	14	61	96	1	31	1

Table 1

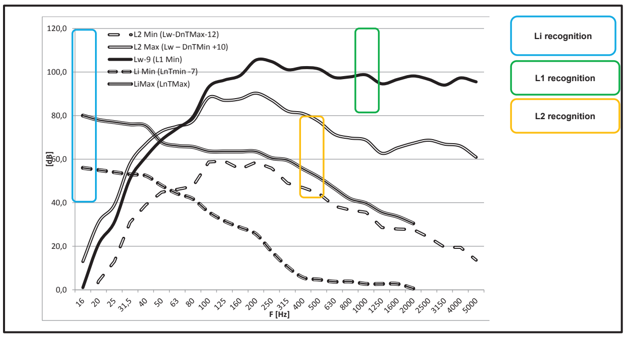

Figure 2

4. Default detection parameters

Based on the statistical analysis exposed above, the following parameters can be used for measurement setups:

Event	For 1/3oct analysis	For 1/1 oct analysis
1	40 dB@500 Hz	45 dB@500 Hz
2	40 dB@500 Hz and pre+post-trigger	45 dB@500 Hz and pre+post-trigger
3	50 dB@10 Hz	50 dB@8 Hz
4	85 dB@1 kHz	90 dB@1 kHz
5	128 dB@LCPk	128 dB@LCPk

Table 2

5. Priority for recognition of the type of measurement

A detection priority is programmed in order to improve the recognition process:

Priority	Detected event	Measurement type
1	5	RT impulse
2	1+2+4	L1
3	1+2+4 then none	RT interrupted
4	3	Li
5	1+2	L2
6	None	Background noise

6. Practical use of the handheld sound level meter with 3 buttons

6.1 "Ready for measurements" mode

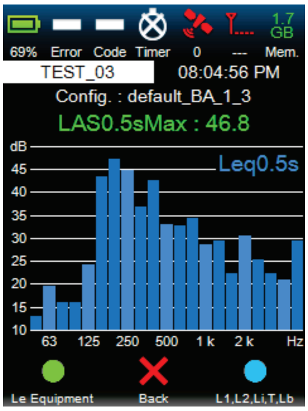

Figure 3

The handheld instrument has 3 command buttons (lower part of figure 3) for easy manual scanned microphone as recommended in [1].

Le Equipment button starts the equipment measurement mode: the instrument logs the time history and stores the LXYMinMax selected in the measurement setup.
L1, L2, Li, T, Lb button starts the multispectrum mode:

6.2 Recording multispectrum mode (average spectrum or reverberation time spectrum)

Once the L1, L2, Li, T, Lb button pressed, the instrument starts the measurement and displays:

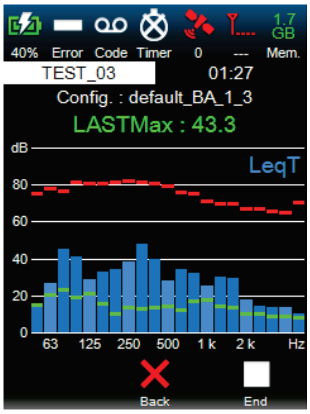

Figure 4

By pressing the End button, the instrument displays a table of measurement types with the recognized type preselected:

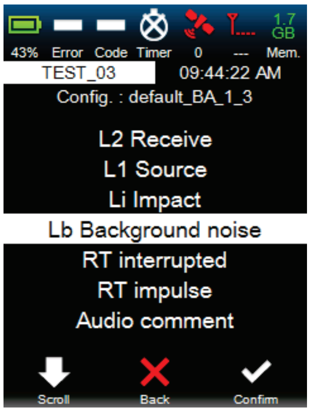

Figure 5

The recognized measurement type is confirmed by pressing the Confirm button.

Note: By pressing the Back button, the user does not store the measurement and the instrument is back to ready for a measurement within the same test.
The operator has also the possibility to force manually a measurement type using the scroll button.

7. Simplified workflow and measurement organization

Once the acquisition type is confirmed, the instrument stores and organizes the data for an easy export to the post processing software:

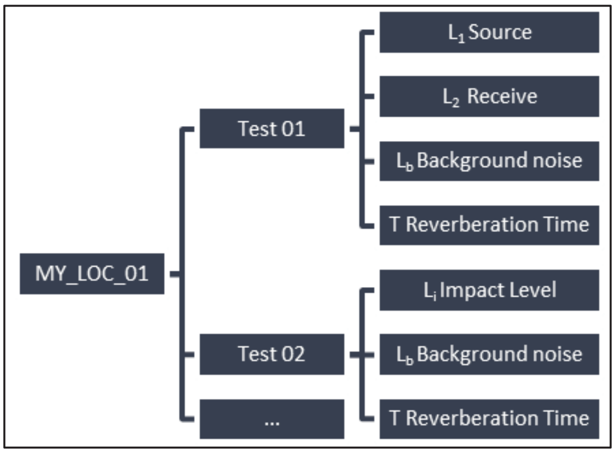

Figure 6

The measurement campaign MY_LOC groups a number of "Test" containers, each of which contains the measurements qualifying one device.

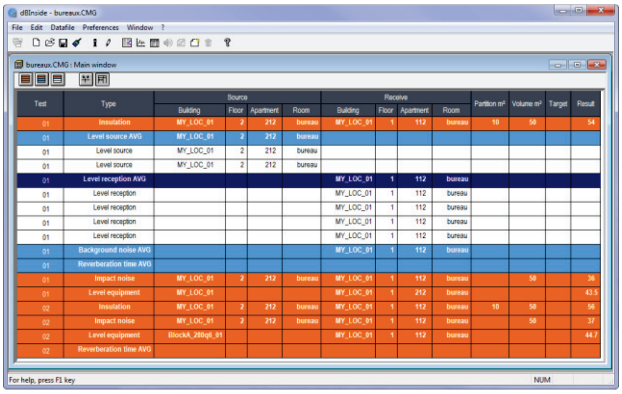

Figure 7

Figure 7 shows the table of results of an imported measurement campaign; data that can be reused for several test results are automatically copied in the right items (typically background noise and reverberation time of the receiving room). The result is directly calculated according to the previously selected standard (figure 8):

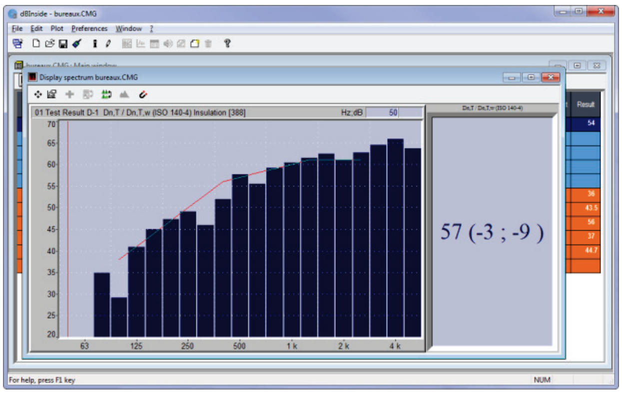

Figure 8

8. Conclusions

The main goal when specifying the building acoustics solution developed in this paper was to facilitate the acquisition and ensure the validity of the measured data in the field.
The workflow as well as the techniques used for automatic detection described in this paper have been thought and implemented for the benefit of the user: when acquiring data on site, main focus is to concentrate on the quality of the measurements without needing to concentrate on how to organize the measurements for fast and efficient post process of data as well as reporting.

The automatic detection technique being innovative, a patent has been submitted on the 26th June 2014 [2].

Acknowledgement

Special thanks to the development team of this project, especially Gilles Barres [3], Benoit Gravier [3], Christian Simonet [3] and Sylvain Zangiacomi [3] for their responsiveness and their programming skills.

References

[1] ISO 16283-1:2014. Acoustics —Field measurement of sound insulation in buildings and of building elements —Part 1: Airborne sound insulation

[2] "SCALA" patent pending under number of deposit 14 55976

[3] ACOEM Dedicated Software Solutions Managers