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SAMSoft: Acoustic device automatic measurement system software

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Abstract

A common way to experimentally characterize a linear time-invariant acoustic system is by measuring its impulse response for each location of interest. Currently several methods exist for such purpose, being signal deconvolution the one which exhibits better performance. Moreover, measurement systems are usually aimed to particular applications, working with expensive platforms and proprietary software. In this paper design and development of specific software called SAMSoft, which manages an automatic measurement system for acoustic devices, are described. SAMSoft presents a modular, scalable and easy to upgrade design developed in Matlab, based on the model-view-control system pattern which enables source code reuse and simple functionality expansion. Application allows impulse response measurement with different excitation signals, time windows introduction to obtained measurements, time and frequency domain visualization, and spectral analysis in octave and one-third octave bands. It runs on a hardware based on a control unit and a mobile platform, being capable of measuring 360º in the horizontal plane with an angular resolution of up to 0.06º. Impulse response of different acoustic transducers measured showed a signal noise ratio of up to 40 dB in frequency bands under 100 Hz. In power measurements for octave and one-third octave bands a maximum error of 0.12 dB was obtained.

Keywords: impulse response, directivity, acoustic measurement system, deconvolution

SAMSoft: Acoustic device automatic measurement system software

1 Introduction

In the field of acoustic metrology is significant to have a system that performs automatic measurements standardized. Currently, audio companies and academic institutions offer different specific applications to measure impulse response (IR), calculation of acoustic parameters and frequency analysis of acoustic devices [1] [2] [3]. Commercially measurement systems are offered with proprietary software applications limiting the kind of data that can be obtained. In academia some applications developed used modern techniques to obtain accurate and plausible results. In this context, the development of an innovative platform that enables the implementation of multiple applications on the same automatic measuring system for characterizing several acoustic devices is presented. In this work, the software called "SAMSoft" (for its acronym in Spanish) is presented, which together with a specific hardware are part of acoustic device automatic measurement system (called "SAMDA", for its acronym in Spanish). SAMSoft presents a modular, scalable and easy to upgrade design developed in MatLab, based on the model-view-control system pattern which enables source code reuse and simple functionality expansion. This software is in constant development and modification. The paper is organized as follows: section 2 the SAMSoft, architecture, basic and specific modules (available in version 2.0 and used to calculate directivity parameters) are described. Additionally, others applications that can be integrated to the system in the future are mentioned. In section 3, the results of directivity measurements are analyzed, evaluating the results through the signal to noise ratio and spectral power one-third octave bands. The results are contrasted with other products of similar performance. On the other hand, an analysis of the system hardware requirements is performed. Finally, in section 4 conclusions are presented.

2 Acoustic device automatic measurement system software

2.1 Software architecture

The Model-View-Controller (MVC) pattern is a software architecture that separates the functionality in three layers.

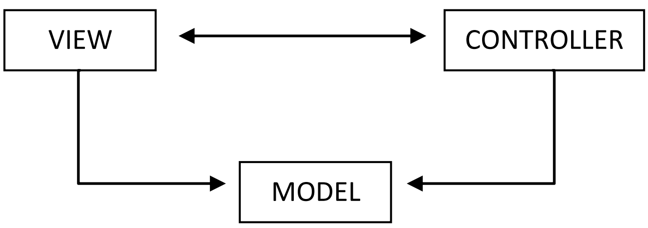


Figure 1: Schematic of interaction MVC

A scheme that specifies the interaction between layers is shown in Figure 1. The *model* handles data and processing thereof, the *controller* manages user commands and is responsible for requesting data to model and communicate them sight. The *view* is the visual representation of data (graphical interface).This scheme allows upgrades and modifications without affecting other parts of the code and basically the model is completely separate from the user interface and has no knowledge of view, or the controller therefore does not have any reference to these [4]. Codes independence is important because it can replace the model, view or controller, which allows to design each part of the program separately. Figure 2 shows the MVC architecture in its most general form in which there is a single model. Multiple controllers manipulate the model and display multiple views of the model data.

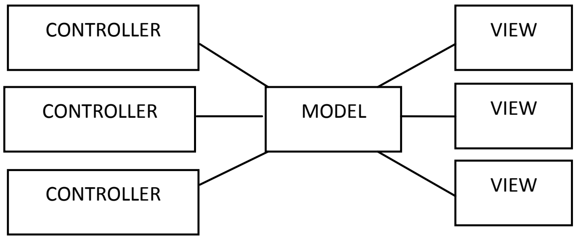


Figure2: Generic scheme MVC

The software brings together *functions* and *classes* that allow you to perform calculations, signal processing and hardware management which are grouped into *basic modules*. The functions and classes that result in different advanced applications are grouped into *specific modules.*

2.2 Model: Basic modules

Classes and functions allow to manage the features, perform processing and contain information. Some of this information may be shared between applications. The most important basic modules are the measurement of the impulse response, filtering process and control the turntable. For handling audio signals, the SamdirAudio class was implemented, it is designed for code reusability and continuous updates, the idea was based on software development ITA-Toolbox [5]. In Figure 3, the class diagram, in which you can see how it manages information signals containing data available to the user both time domain and the frequency domain is shown.

2.2.1 Impulse response measurement

Different techniques are used to measure the impulse response. Deconvolution technique has the advantage of obtaining the impulse response of the system perfectly separating nonlinear effects thereof, by applying a signal of sinusoidal sweep exponential variation as excitation and corresponding inverse filter [6]. Thus, it is possible to eliminate distortions through appropriate time windows.

The function that performs this measurement in SAMSoft is:

Syntax: *[samdirAudio, samdirAudio]= samdir_measure_ir_exponential(samdirAudio)* *(1)*

The calculation of the impulse response by the above function only requires an object parameter of type *SamdirAudio* with the excitation signal. The function returns the impulse response and the recorded signal.

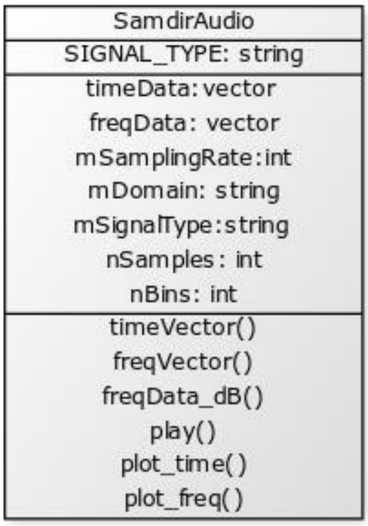


Figure 3: Class diagram

Generating filter,
Syntax:

samdirAudio = samdir_inverse(samdirAudio, [FrequencyRange]) (2)

Generation sweep through *samdir_generation()* requests several parameters to achieve an appropriate outcome, including the frequency range, sampling frequency and it is also possible to add a margin of silence at the end of the scan to retrieve the tail the impulse response, if this is longer than the excitation signal [7].

2.2.2 Time windows

Applying Matlab window function, which returns a window in time to pass the type and quantity of samples, SAMSoft adds another parameter, *orientation*: left or right. The syntax of the function is shown below:
Syntax:

window=samdir_window(long, 'type',orientation) (3)

This function is used to apply a time windows to a specific signal, which must specify the type of time windows that needs to be applied, the period at the beginning and end, the signal to which the window will be applied and if has silence at the end.

2.2.3 Filters

The software has the capacity to generate different types of filters of variable order, both octave band and third octave. By default, the filters used are Butterworth type and 6th order, meeting the specifications of international standard IEC 61260 [8].

2.2.4 Associated hardware control

An important set of functions that are part of SAMSoft are those dedicated to the control of the rotating platform. It consists of a step mechanical gearbox coupled to a stepper motor, whereby 0.06º angular resolution is achieved, exceeding the typical requirements of laboratory tests performed. Communication is carried on via a USB connection.

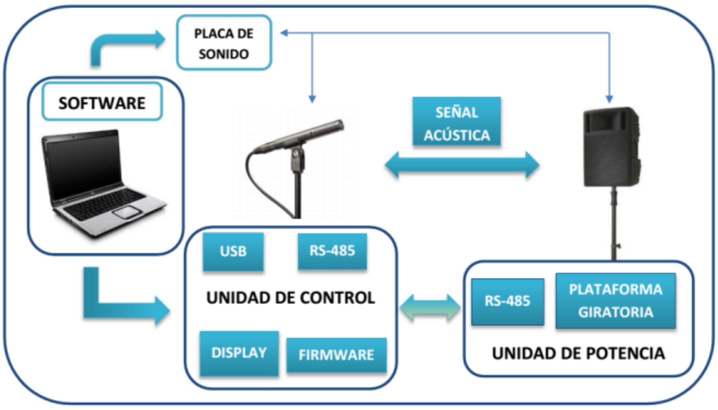


Figure 4: Communication system diagram.

Among the parameters available for control are the same rotation direction and angle of movement. This module is responsible for initialize, configure and control data acquisition devices. As for the configuration of input and output audio channel, SAMSoft supports the use of PC sound card, using functions *analog input* y *analog output* acquisition toolbox of Matlab data.

2.3 Model: specific modules

The platform developed allows evaluating different characteristics and types of acoustic devices in the same measurement system. SAMDir v1.0 [9] is the specific application implemented to evaluate the directivity of electroacoustic transducers (transmitters and receivers), currently available version 2.0. Moreover, SAMAbs is the application that measures the sound absorption coefficient of a material and SAMDif is used to measure sound diffusion coefficient. The latter two applications are currently in research and development stage.

2.3.1 SAMDir v2.0

Version 2.0 (released in 2014) presents improvements over the previous both the visual appearance and functional. The new interface, shown in Figure 5, can load a user configuration; different excitation signal from a file, as well as generate from the program; filters for frequency analysis of the signals obtained, among others. In addition, the interface lets the user to browse different tabs that are enabled once the processing was done. Each graphed signal can be displayed in a Matlab window and it can be manipulated in that environment.

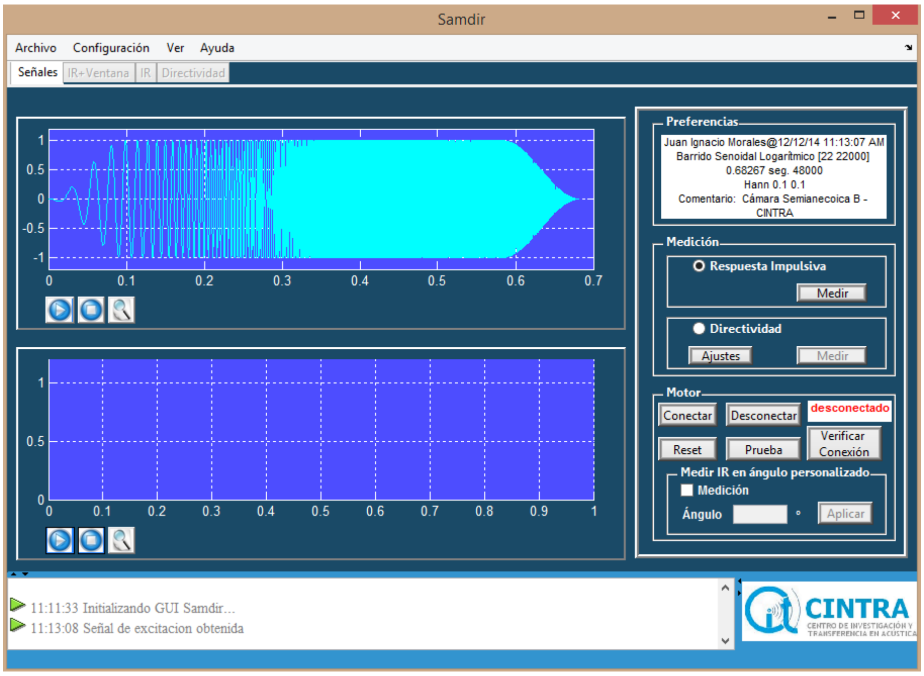


Figure 5: GUI SAMDir v2.0

2.3.2 Directivity diagram

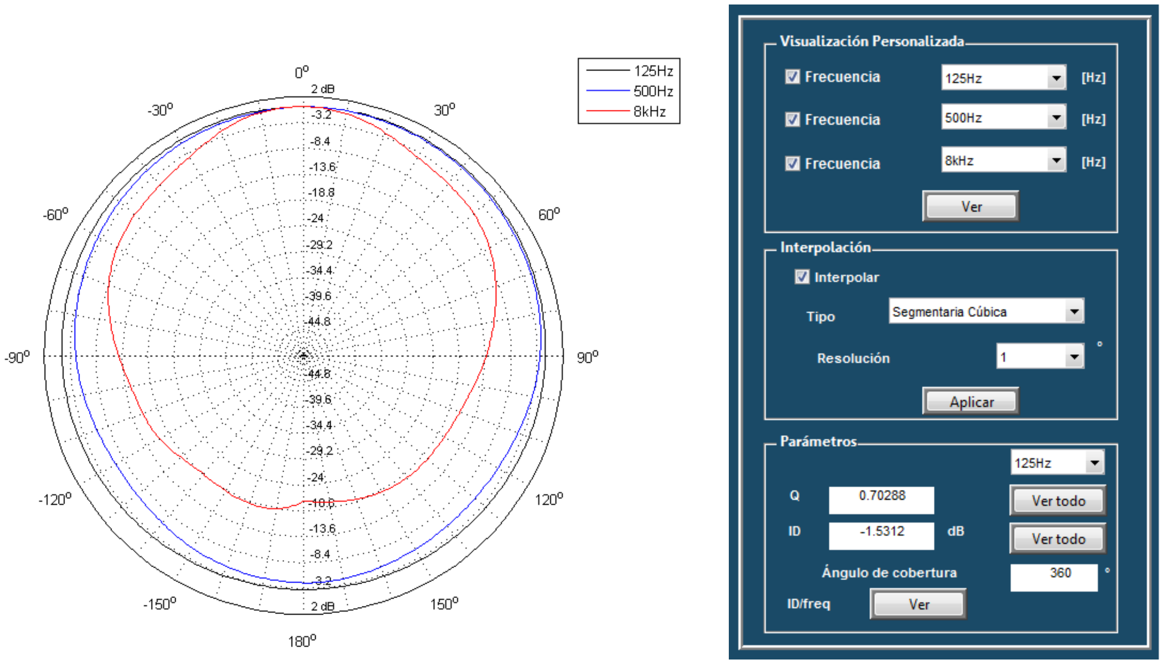
The directivity pattern by octave or third octave on the horizontal or vertical plane of the evaluated device is generated by user's request and processed by the *samdir_directivity()* function, it receives as a parameter An object of the class of SamdirAudio (an impulse response). To plot directivity a variation of Steve Rickman script is used [10]. The result is shown in Figure 6a. In some cases it is useful to present the data by applying some kind of interpolation, this option is available as shown in Figure 6b. Finally, the function gets the angle of coverage (C_L), the directivity index (DI) and directivity factor (Q). The latter two vectors are depending on the angle.

3 Experimental test

In order to perform a validation of the designed system, several measurements were carried out. The results were compared with the outputs of B&K 7841 (Dirac v3.0) and Aurora v4.0 (plugin Adobe Audition).

3.1 Test configuration

For the test a sound card integrated into a notebook Sony Vaio, Intel i5-3210, 2.5 GHz, 6 GB RAM, Windows 8.1 Pro operating system was used. The line input was connected to the audio output via cable 1 m long.



a) b)

Figure 6: a) Directivity diagram obtained with a speaker, SAMDir v2.0; b) Options directivity

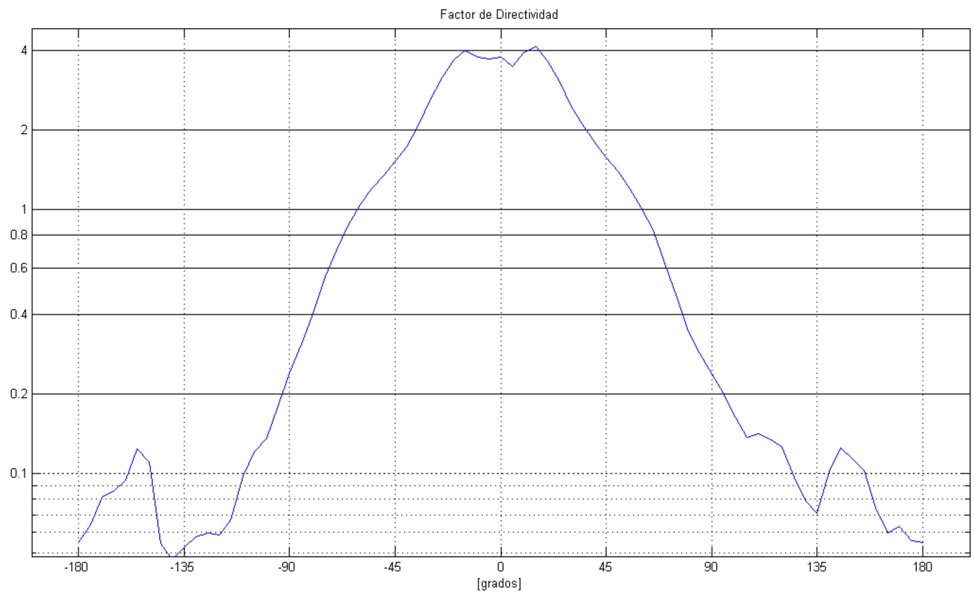


Figure 7: Directivity factor obtained with SAMDir v2.0

To measure the signal to noise ratio (SNR) of an impulse response , the system is excited with a sine sweep exponential signal, with a frequency range of 22 Hz to 22 kHz, duration 2.73 s, Hanning window 0.1 s at both ends sweep, 48 kHz sampling frequency and channel. They recorded those obtained IR extension .wav files with a sampling frequency of 48 kHz and 16 bit resolution. Files were loaded on B&K 7841 and the SNR was calculated by bands of third octave.

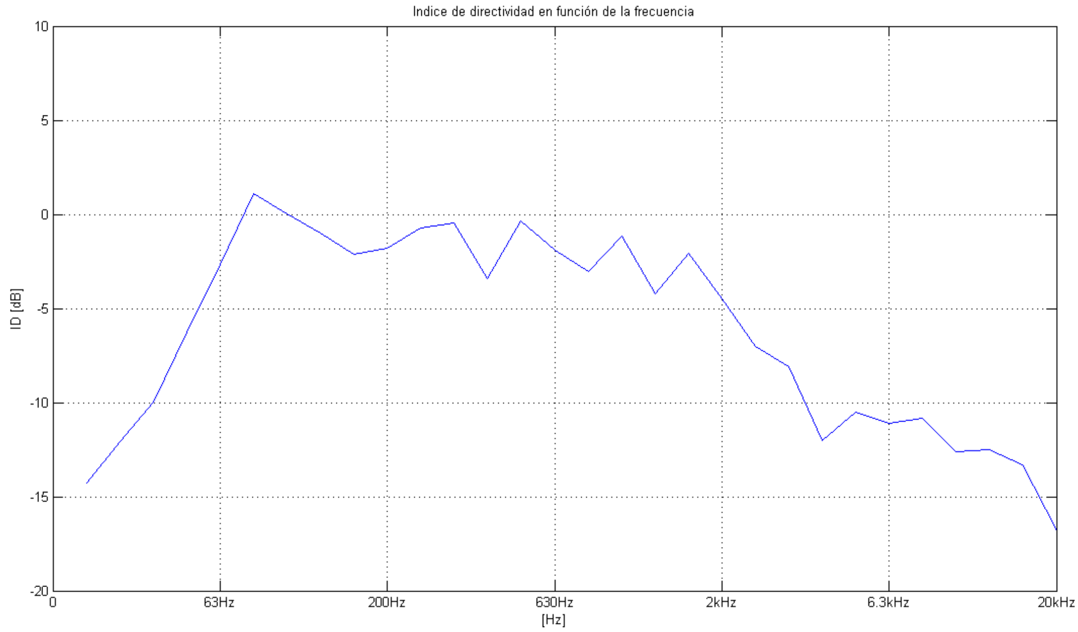


Figure 8: Directivity Index as function of frequency obtained with SAMDir v2.0

3.2 Results

The results are shown in Table 1. It is noted that the IR Dirac obtained has an average SNR 59 dB, although this is less than 36 dB for the frequency range 31.5 to 63 Hz. The obtained IR Aurora has a SNR average of 43 dB, being less than 36 dB in the spectral bands mentioned. The IR achieved by SAMDir v2.0 has a value close to 55 dB average, with values greater than 45 dB for the 50 and 63 Hz, and values above 65 dB at the highest frequency range (from 3.15 kHz, except 20 kHz). Bold values where the software has better performance SAMDir are highlighted.

Table 1: Comparison of SNR of IR measurement with different systems [dB].

f [Hz]	DIRAC	AURORA	SAMDIR	f [Hz]	DIRAC	AURORA	SAMDIR
25	52	20	21	**800**	67	46	55
31.5	33	23	24	**1000**	68	46	58
40	33	31	32	**1250**	66	46	59
50	34	36	**45**	**1600**	68	46	62
63	35	36	**48**	**2000**	67	45	62
80	48	43	47	**2500**	65	46	61
100	42	43	**47**	**3150**	66	46	**67**
125	66	44	49	**4000**	67	46	**68**
160	55	45	49	**5000**	65	46	**68**

200	63	46	50	**6300**	65	46	**69**
250	63	46	50	**8000**	65	46	**68**
315	67	46	50	**10000**	65	46	**69**
400	67	46	51	**12500**	64	46	**68**
500	68	46	53	**16000**	64	46	**67**
630	66	46	55	**20000**	58	38	**62**

To analyze the accuracy in computing the spectral power, two types of signals generated SAMDir were used:

a) Exponential sine sweep of 22 Hz to 22 kHz, 10.92 s duration without time window.

b) White noise, same duration.

Both signals were recorded in .wav 48 kHz sampling rate, 16 bit resolution. The files were loaded into the B&K7841 and SAMDir program, where filters were used bandpass third octave of sixth order Butterworth type according to IEC 61260.

The values obtained from the test are shown in Table 2. It can be seen that the maximum error is 0.12 dB, considering negligible for this type of measurement.

Table 2: Spectral power for third octave [dB].

f [Hz]	Barrido Exponencial		Ruido Blanco		f [Hz]	Barrido Exponencial		Ruido Blanco	
	DIRAC	SAMDIR	DIRAC	SAMDIR		DIRAC	SAMDIR	DIRAC	SAMDIR
25	-0.31	-0.31	-28.54	-28.66	**800**	-0.1	-0.03	-14.09	-14.08
31.5	0	0	-27.39	-27.37	**1000**	-0.1	-0.03	-13.1	-13.08
40	-0.08	-0.03	-26.81	-26.92	**1250**	-0.1	-0.03	-12.05	-12.04
50	-0.09	-0.03	-26.16	-26.22	**1600**	-0.1	-0.03	-11.09	-11.08
63	-0.09	-0.03	-24.5	-24.51	**2000**	-0.1	-0.03	-10.06	-10.04
80	-0.09	-0.03	-24.03	-24.09	**2500**	-0.1	-0.03	-9.06	-9.05
100	-0.09	-0.03	-23.22	-23.17	**3150**	-0.1	-0.03	-7.91	-7.90
125	-0.1	-0.03	-22.28	-22.3	**4000**	-0.1	-0.03	-7.11	-7.07
160	-0.1	-0.03	-20.93	-20.91	**5000**	-0.1	-0.03	-6.02	-6.01
200	-0.1	-0.03	-19.93	-19.98	**6300**	-0.1	-0.03	-5.05	-5.05
250	-0.1	-0.03	-18.92	-18.88	**8000**	-0.1	-0.03	-4.03	-4.01
315	-0.1	-0.03	-18.2	-18.2	**10000**	-0.1	-0.03	-3.05	-3.04
400	-0.1	-0.03	-17.05	-17.03	**12500**	-0.1	-0.03	-2.03	-2.02
500	-0.1	-0.03	-16.01	-15.99	**16000**	-0.1	-0.03	-1	-0.99
630	-0.1	-0.03	-14.93	-14.92	**20000**	-0.44	-0.38	0	0

Another relevant analysis is the runtime measurement. To estimate this time, he turned to *the tic / toc* MatLab functions. Using a signal of 10.92 s (524288 samples for 48 kHz sampling rate), the following values were obtained:

a) The measurement of RI of a system (comprising signal generation, windowing, inverse filter generation, recording and deconvolution) is performed in 13.6 s ± 0.1 s.
b) Filtering and power calculation bands third octave is performed in 4.2 s ± 0.1 s.

4 Conclusions

Validations made the system developed by evaluating the SNR and spectral power for third octave are satisfactory compared to the values obtained with other commercial systems. The system evidenced low runtimes in RI measurements (13.6 s ± 0.1 s) and calculation of power by bands of third octave (4.2 s ± 0.1 s). The results of the measured directivity descriptors are high precision (angular resolution of 0.06º) and repeatability (error of 0.12 dB). The program developed by its modular structure allows scalability and fast update, allowing multiple specific applications and reusing basic modules.

Acknowledgments

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