ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

DEVELOPMENT OF A TWO-AXES POSITIONING SYSTEM WITH APPLICATION IN ACOUSTIC SCANNING

Douglas Iceri Lasmar, douglaslasmar@ufmg.br
Gilva Altair Rossi, gilva@ufmg.br
Antônio Augusto Torres Maia, aamaia@ufmg.br
Lazaro Donadon, lazaro@ufmg.br
Jose Maria Galvez, jmgalvez@ufmg.br
Universidade Federal de Minas Gerais, Departamento de Engenharia Mecânica
Av.Antônio Carlos, 6627, Pampulha, 31270-901, Belo Horizonte – Minas Gerais - Brasil

Abstract. *In this work, an automated system for data collection and measurement of sound pressure was developed. Through a supervisory system, the user creates a two-dimensional grid and commands the start of the measurement procedure. The system will command the sensor positioning at each grid point, and then, make the measurement at each point and store the data in a file for a future analysis. In this work will be presented the development of the system and some preliminary tests.*

Keywords: *Automatic measurement , Acoustic measurement , positioning system.*

1. INTRODUCTION

Traditionally detection of sound sources has been done with microphone arrays and through processing individual microphone signals. A critical aspect is to distinguish true targets from noise peaks. One method in particular, the Phase Transform (PHAT) has demonstrated improvements in sound sources images especially in reverberant and noisy environments. Several applications have become relevant in modern live: pass-by noise tests are useful for determining the sound level of noise sources on a vehicle during operation. These are often measured to ensure compliance with local and federal laws that govern acceptable sound emitted from a vehicle to produce minimal traffic noise. Pass-by noise source identification takes this one step further by identifying the source of the noise as well, so engineers can fine-tune vehicle design to minimize noise. The same techniques can be applied to more than just automobiles. Boeing has used acoustic beam forming to locate and reduce noise on aircrafts, and the Korean Railroad Research Institute has used it to reduce noise emissions on high-speed KTX trains. However these techniques have several challenges including simultaneous acquisition of a large sensor array, advanced signal processing and storage of extremely large data sets, Microphone arrays are complex sensors. To function properly, they usually require a large amount of signal conditioning hardware and data acquisition hardware including excitation, anti-alias filtering, simultaneous sampling, and high streaming rates (Carneal et al, 2006; Johnson et al, 2006; Aarabi, 2003).

Manual data collection is a process of limited reproducibility and usually depends on the skill and availability of the researcher that conduct the experiment. The need for automation in data collection increases as the number of data to be acquired increases.

This paper presents the development of a simple solution for automated of acoustic measurements in a two-dimensional grid. It eliminates the need for a several microphones array by using a accurate positioning system that transport a single microphone. The proposed system can be used to determine acoustic features of environments and materials. One of the great difficulties in this area is centered on the issue of noise and therefore the transmissibility sound. Therefore, it has been necessary to seek new methods that allow greater efficiency in studies of materials analysis. The application of automation techniques for acoustic measurement systems allows shorter time of data collection, greater repeatability, reproducibility and process control.

The work can be divided into three main stages. The first stage was the development and assembly of the mechanical structure that comprises two axes. The acoustic sensor is fixed on the vertical axis. In the second part of the project, it was developed the control module position, responsible for the correct positioning of the sensor. In the third stage, it was developed the software for data acquisition and for supervising the system.

2. METHODOLOGY

This system consists of a mechanical structure, which has vertical and horizontal axles, and whose function is to place the acoustic sensor in predefined points of a two-dimensional grid. The acoustic signals measured by the sensor are recorded and processed in the acquisition/ supervision module. The main steps of this work are described briefly below:

ISSN 2176-5480

First Step: Design and construction of the two-dimensional positioning system, the axis X and the axis Y;

Second Step: Installation of motors of each axis and the acoustic sensor;

Third Step: Design and implementation of a control system for positioning the axes. The control module will control the position sensor based on a grid position predefined by a system supervisor;

Fourth Stage: Development of a supervisory system configurable with graphical interface for presenting data to the user and additional technologies such as remote access. The grid is defined by the system, ie, the set of points the sensor will be positioned in order to collect the acoustic signals. The collected data is processed and presented graphically and through digital record. The supervisory system commands the position control system which in turn will command the mechanical structure that leads the sensor positioning;

Fifth Stage: Experimental validation of the prototype.

3. MECHANICAL ASSEMBLE

The horizontal axis has a millimetric resolution. The assembly of the horizontal axis is represented schematically by Fig. 1 (Igus, 2011), wherein the stroke is 1200mm, and supports load of up to 1600N, as well as displacements of up to 1 meter per minute.

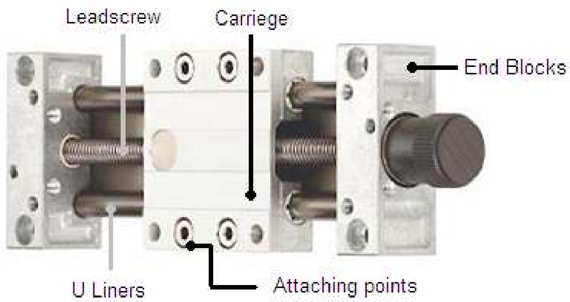

Figure. 1 Horizontal Displacement Axis.

The vertical axis shown in Fig. 2 (Igus, 2011), has an axial load capacity of up to 200N and an radial load of up to 400N, enough to support a acoustic sensor with mass less than 300 grams.

Figure 2. Vertical Displacement System.

As link between the horizontal and vertical displacement axis, it was used a coupling, as showed in Fig. 3. The coupling is fixed at the horizontal carriage by four screws and has a U-shaped to enable the accommodation of the step motor responsible for the vertical displacement; an extra tubular coupling, showed in Fig. 6, allows the connection between the motor and the vertical spindle. Stepper motors were used to drive the vertical and horizontal axes, which have step 1.8 º (200 steps per revolution) and torque of 0.8 Nm.

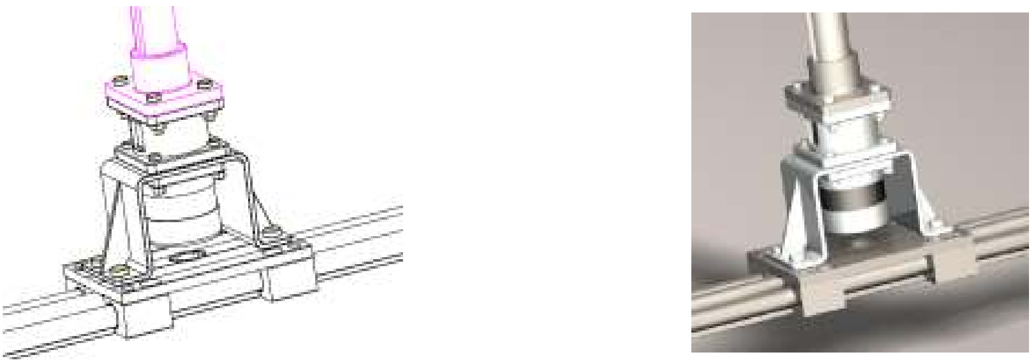

Figure 3. Link Between Horizontal and Vertical Displacement Systems

ISSN 2176-5480

The assembly of the complete system is as shown in Fig.4 where the three views of the mechanical displacement system and its dimensions are presented.

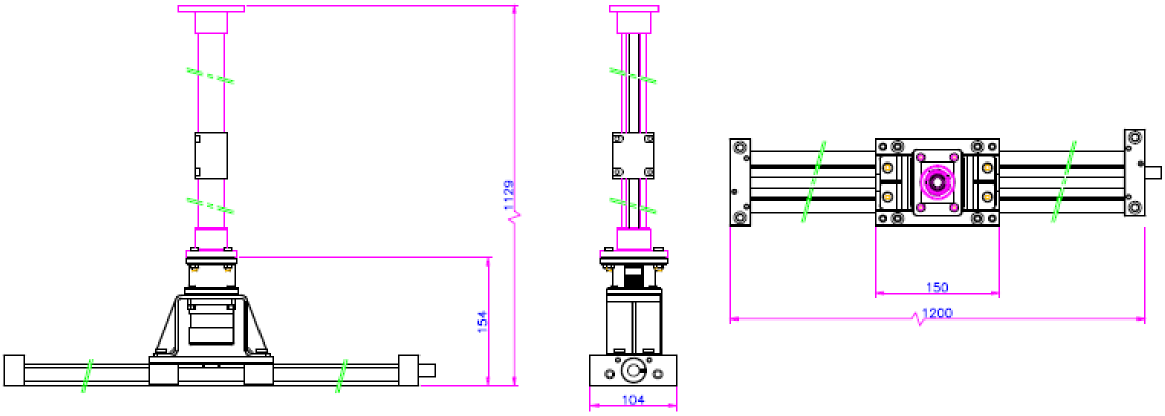

Figure 4. Mechanical Displacement System

The acoustic sensor used was the model 130E20 (1/4”) manufactured by PCB Piezotronics Inc. The main feature observed for the acoustic sensor choice was the frequency range of operation, as in many studies analyzed (as Garcia et al, 2008; Donadon et al, 2008 , Kruszielski et al, 2010), the measurement range of frequency was always below 10 kHz, this was the chosen limit. This sensor is suitable for sound emissions from one direction and for use in a controlled environment, with low disturbance. The fixing of acoustic sensor along the Y axis can be seen in Fig. 5

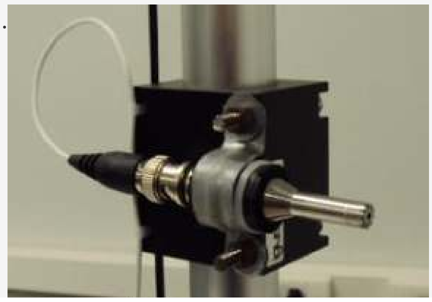

Figure 5. The Acoustic Sensor

FIG. 6 shows the assembly of the system with its vertical and horizontal axes, with a acoustic sensor coupled to the vertical axis. Under the workbench are distributed the supervisory system and the positioning control module.

ISSN 2176-5480

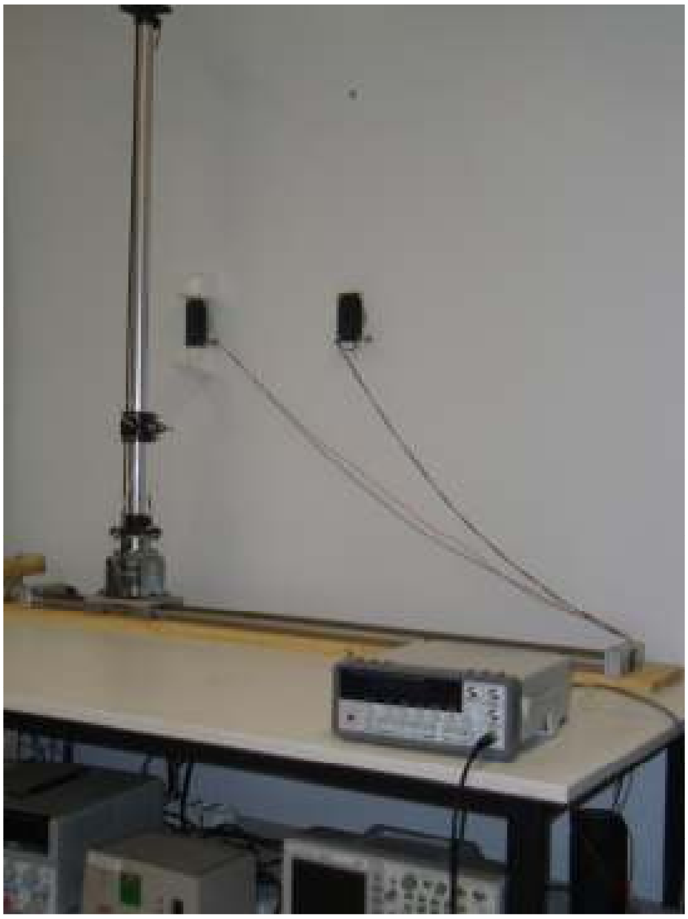

Figure 6. Prototype of the Automated Measurement System

4. THE POSITIONING CONTROL: HARDWARE AND SOFTWARE

The supervisory system is responsible for calculating the set of coordinates from the user-supplied parameters, send and receive information from the positioning system, and store the data sent by the acoustic sensor. It is through the supervisory system that the user defines the two-dimensional grid. Then, the measurement procedure is initialized. The supervisory system sends the XY coordinates to the positioning module, which controls the motors of axes X and Y. When the commanded position is reached, the positioning module communicates this fact to the supervisory system and stays waiting for a new command position (Lasmar et al,2010a). The supervisory system performs the signal acquisition sent by the acoustic sensor. This procedure is repeated until all the grid is scanned.

5. SOFTWARE ALGORITHM

The software system consists of two algorithms. The first algorithm, installed in the positioning module, is showed in the flowchart of fig. 7. This software is responsible for converting the XY coordinates sent by the supervisory system in the command signals to the motors. And the control software also informs the supervisory system the current coordinate of the acoustic sensor.

ISSN 2176-5480

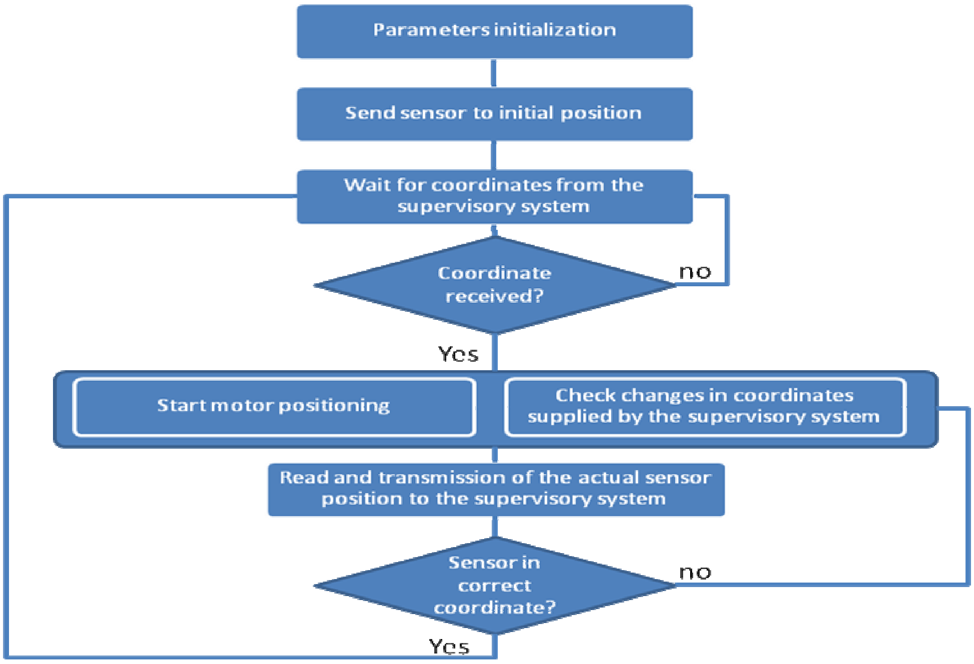

Figure 7. Positioning Algorithm Flowchart

The second algorithm is performed by the supervisory system and, has the function of inform the positioning system the coordinates of the acoustic points to be surveyed. Figure 8 shows the supervisory system flowchart and a brief description is presented below.

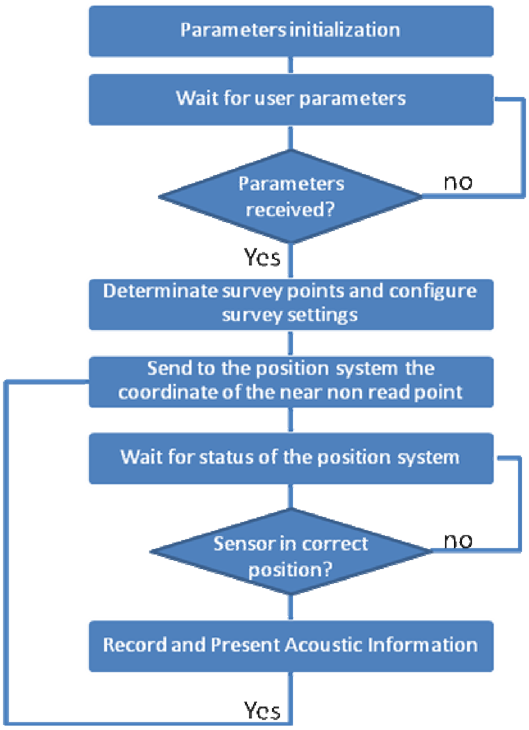

Figure 8. Supervisory System Algorithm

In step "Parameters Initialization", is determined libraries that will be used and the characteristics of the display windows of the user interface. In step "Wait for User Parameters", the program waits information such as number of points to be recorded in the vertical and horizontal direction, recording time and distance between points.

Then, with the data provided by the user, the program will determine the points where the sensor will collect the measurements. Then, the supervisory system provides for the positioning control module, the XY coordinate required. As soon as receive this information, the control module commands the sensor to the required XY position.

ISSN 2176-5480

In step "Sensor in Correct Position?" supervisory system waits until it receives information from the positioning system that the desired position has been reached. Finally, the supervisory system will record the information collected by the sensor. This procedure is repeated until the total number of mesh points is covered by the sensor.

The graphical interface of the supervisory system is presented in Fig. 9. The top window (1) contains the measurement parameters, the window (2) shows the current position of the sensor and the window (3), the path traveled by the sensor. Only the window (1) needs to be filled, the remaining fields will be automatically updated. Figure 9 also has a window in the lower position, where the data collected in the time domain are presented, as well as its Fourier transform.

It is noteworthy that the points defined for data collection are calculated automatically by the supervisory system from the initial position parameters X and Y, ie, the number of points in X, the number of points in Y, the distance between points in X and the distance between points in Y.

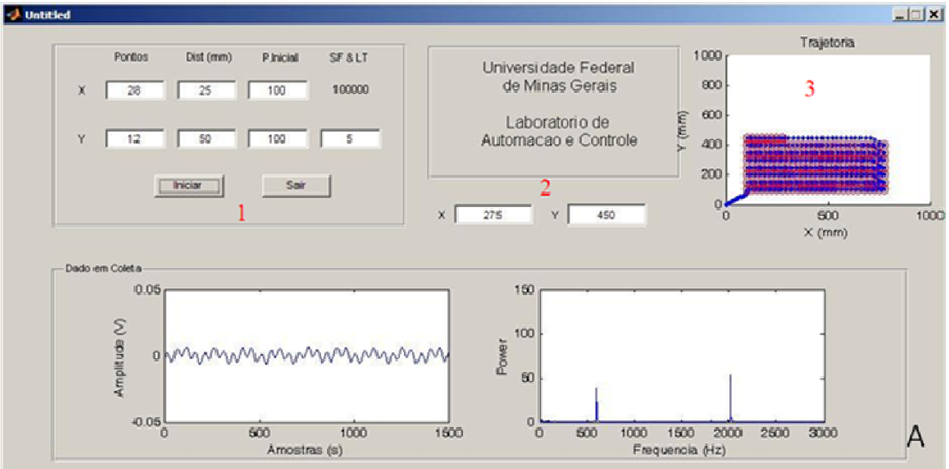

Figure 9. Graphical interface of the supervisory system

6. RESULTS

To validate the measurement capability of the prototype, two acoustic sources were installed in fixed positions and excited by a sinusoidal electrical signal. Figure 10 shows the complete system where it is observed the background acoustic sources and the acoustic sensor coupled to the vertical displacement axis. The system was parameterized to make measurements over a predefined grid (this grid is represented in the figure).

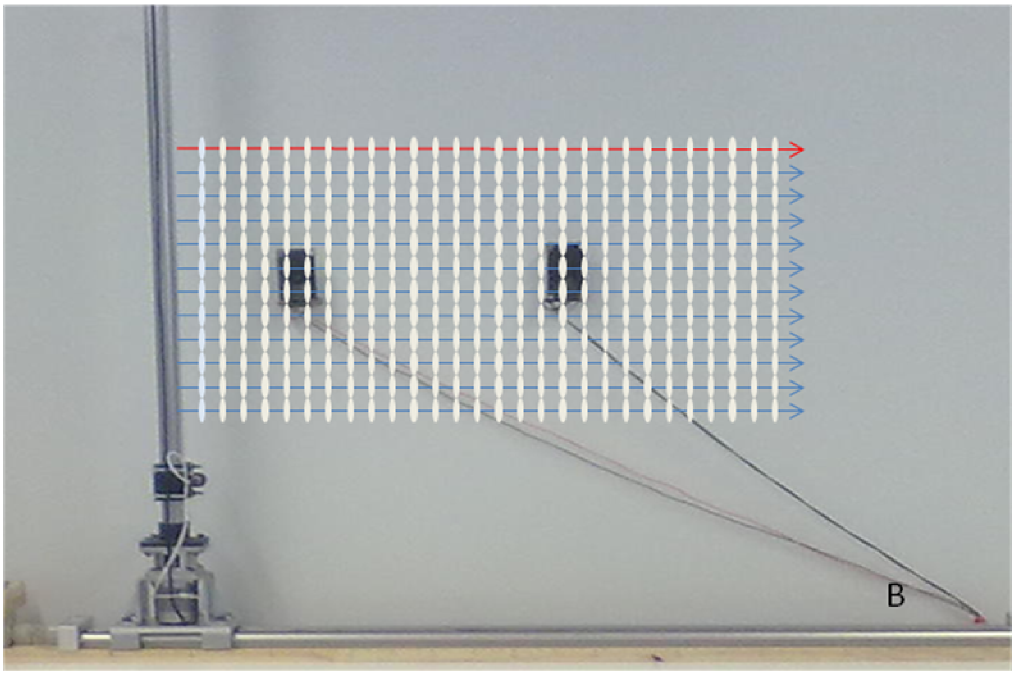

Figure 10. Experimental Tests Measurement

ISSN 2176-5480

In the test shown in Figure 10, the first acoustic source emits sinusoidal signal of 600Hz, and the second source emits sinusoidal signal of 2000Hz. The sources were respectively fixed at positions (X150, Y310) and (X480, Y310) of the measurement panel. In Fig. 11, which presents the data collected during the test, it is possible to observe a greater sound pressure near the points where the sources are fixed. The sound pressure is measured in every grid point and the values recorded.

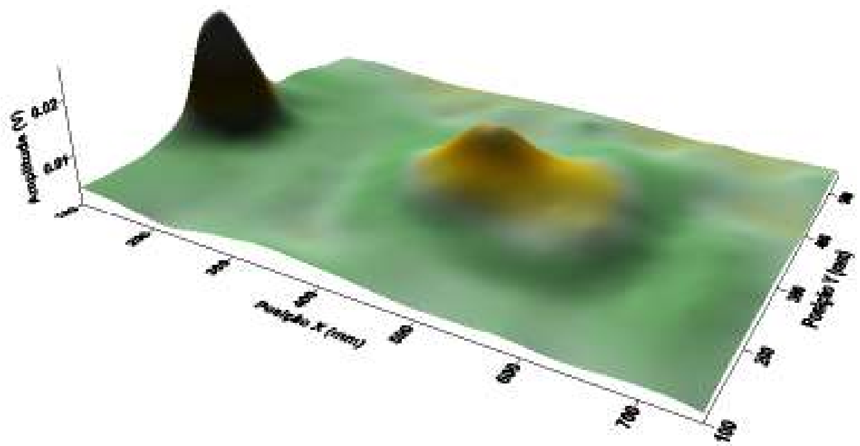

Figure 11 – Sound Intensity

FIGURE 11 presents the data in the frequency domain in the range of 0 to 1500Hz.

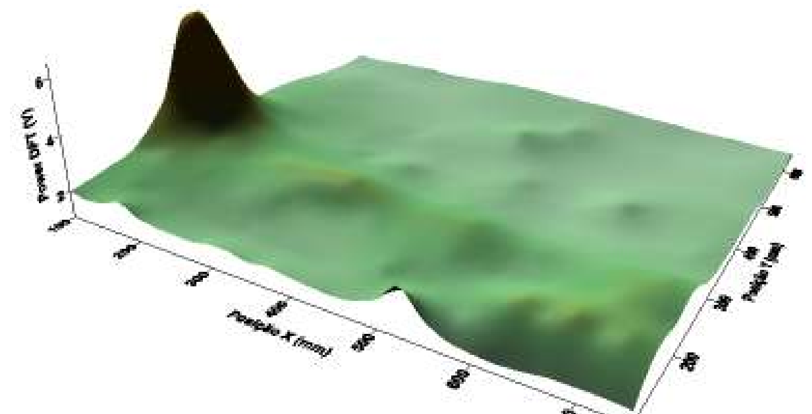

Figure 12. Results in Frequency Domain

7. CONCLUSIONS

This paper shows the main aspects involved on the development of the automated measurement system. The prototype has a two-dimensional positioning system. It was manufactured and validated (Lasmar, 2010b), and exhibited low positioning error in horizontal positioning (error less than 1mm) and vertical positioning (error less than 0.5mm).

The supervisory system was developed with a friendly graphic interface, which allows real-time visualization of acoustic signals measured in the environment. These data are stored and can be processed appropriately according to the application. The measuring system proved to be efficient.

The proposed system is easy portable and versatile enough to be used in several applications. However to achieve its best performance, it still requires some signal conditioning and data acquisition hardware and also signal processing software to cope with some difficulties in this area, such as, discriminating true sound sources from noise peaks, aliasing and accurate identification of sound sources images in reverberant and noisy environments.

8. ACKNOWLEDGEMENTS

This work was only possible thanks to the resources of FAPEMIG.

9. REFERENCES

Aarabi, P., The fusion of distributed microphone arrays for sound localization, Eurasip Journal on Applied Signal Processing, v 2003, n 4, p 338-347, Mar. 2003.

Carneal, J., Johnson, M., Gillett, P.,"Comparison of a Diffracting and a Non-diffracting Circular Microphone Array," Proceesing of ICASSP 2006, Toulouse, France, May 14-19, 2006.

Donadon, L. V., Siviero, D. A., Pasqual, A. M., Arruda, J. R. F., 2008, "Determinação Experimental de Perda de Transmissão Sonora em Painéis", Proceedings of the XXII Encontro da Sociedade Brasileira de Acústica.

Fahy, F.J., 2001, "Foundations Of Engineeding Acoustics", Academic Press.

Garcia, Daniela B., Vecci, Marco A. M., Rodrigues, Francisco C.. Avaliação de Isolamento Sonoro Aéreo de Elementos de Vedação na Construção Civil. Ambiente Construído, Porto Alegre, v. 8, n. 1, p.49-63, jan./mar. 2008.

Igus, Catalogo DryLin, 2011. Disponível em < http://www.igus.com.br >. Acesso em 19 setembro 2011.

Johnson, M., Carneal, J., Gillett, J. " Comparison of a Diffracting and a Nondiffracting Cylindrical Microphone Array," Proceedings of ICSV 13, Vienna, Austria, July 2-6, 2006.

Kruszielski, L.F.; Coelho, R.S.; Zannin, P.H.T., A. Avaliação Acústica da Sala de Gravação do Estúdio de Áudio do Departamento de Artes da Universidade Federal do Paraná. Acústica & Vibrações, Florianópolis, n.39, p.12-22, Maio, 2008.

Lasmar, Douglas I., Gilva, Altair R. J., Maia, Antônio A. T., Galvez, José M. Sistema Digital de Controle em Mesa de Posicionamento. C&I Controle & Instrumentação, São Paulo, v.13, n.162, p.66-71, novembro, 2010a.

Lasmar, Douglas I., Salomé, Alisson F., Maia, Antônio A. T., Gilva, Altair R. J., Rubio, Juan C.. Validação Metrológica Experimental de Sistema de Posicionamento Automatizado. C&I Controle & Instrumentação, São Paulo, v.13, n.163, p.64-70, dezembro, 2010b.

McConnell, K. G., 1995, "Vibration Testing – Theory and Practice", Wiley Inter-Science, New York, United States of America, 261-302 p.

National Instruments, June 2008, "Data Acquisition System: 7 Steps to Success", National Instruments, Austin, USA.

Rao, S. S., October 2009, "Vibrações Mecânicas", Prentice Hall, São Paulo, Brazil, 4ª ed.

8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper