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Design and Characterization of a 2D Array of MEMS Microphones for Acoustical Imaging

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Summary: This paper presents the characterization of each of the MEMS microphones which form a uniform planar array used for acoustical imaging. These microphones show an esentialy flat frequency response, with a ±2dB variation between all sensors. This paper also shows the design and the acoustic characterization of the planar array of MEMS microphones. Analyzing the acoustic array characterization it was observed that as the variations of the measured beampattern, with respect to the theoretical one, are limited, it is not necessary to apply calibration techniques to the array.

Keywords: Characterization, planar array, MEMS microphones, Acoustical Imaging.

1. Introduction

An array is an arranged set of identical sensors, fed in a specific manner. The beampattern of the array can be controlled by modifying the geometry of the array (linear, planar...), the sensor spacing and the beampattern, the amplitude and phase excitation of each sensor [1]. Microphone arrays are a particular case [2].

The authors of this paper have experience in the design [3] and development of acoustic ULAs (Uniform Linear Arrays), formed by acoustic sensors distributed uniformly along a line. In order to obtain spatial information in two dimensions, it is necessary to work with planar arrays with sensors distributed on a surface. Working with planar arrays leads to an increase in both system complexity and space required by the acoustic sensors and the associated hardware.

A typical system has four basic elements: sensors, signal conditioners, acquisition devices and signal processor. For the first three elements, system cost increases linearly with the number of channels, as each sensor needs a signal conditioner and an acquisition device.

Digital MEMS (Micro-Electro-Mechanical System) microphones include a microphone, a signal conditioner and an acquisition device incorporated in the chip itself. For this reason, an acquisition and processing system for an acoustic array based on MEMS microphones is reduced to two basic elements: MEMS microphone and a processing system. The integration of the microphone preamplifier and the ADC in a single chip significantly reduces costs, and also the space occupied by the system.

This paper presents the design and the acoustic characterization of a planar (2D) array of MEMS microphones that will be used to obtain acoustic images of different targets and use them in different applications, such as a biometric system, or noise and vibration analysis.

Section 2 introduces MEMS microphones technology. Section 3 characterizes the frequency response of the microphones used. Section 4 defines the planar array geometry and Section 5 shows its acoustic characterization. Finally, Section 6 contains the conclusions and future research lines.

2. MEMS microphones

The acronym MEMS refers to mechanical systems with a dimension smaller than 1 mm [4] manufactured with tools and technology arising from the integrated circuits (ICs) field.

The application of MEMS technology has allowed the development of high-quality microphones with high SNR (Signal to Noise Ratio), low power consumption and high sensitivity. MEMS microphones consist of two components, the acoustic sensor and the controller circuit [5].

3. Characterization of each MEMS acoustic sensor in laboratory

For the implementation of the array, MP34DT01 microphones of STMicroelectronics, - digital MEMS microphones with PDM interface - were chosen.

MEMS sensor characterization was performed analyzing the frequency response of all MEMS sensors included in the array. A sinusoidal 4ms pulse with a frequency changing between 2 and 18kHz was generated using a reference loudspeaker. All measurements were performed in an anechoic chamber.

The frequency response of each MEMS sensor was obtained and normalized according to the loudspeaker's response. Then, the average of the frequency responses was assessed. Figure 1 shows all the responses.

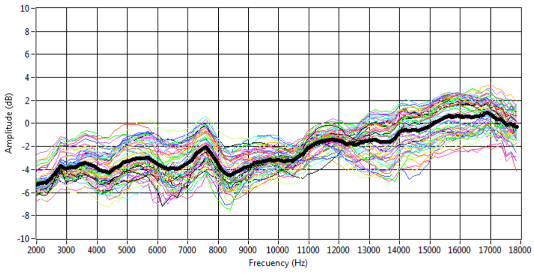

Fig. 1. Frequency responses and averaged response of the MEMS microphone.

It can be observed that the averaged frequency response is essentially flat, with a slight increase at high frequencies. This averaged response is bounded within a range of ±4dB. Figure 1 also shows that the frequency response of MEMS sensors varies in a range of ± 2dB around the averaged value.

4. Array geometry

The array characterized in this paper is based on a Uniform Planar Array (UPA) of MEMS microphones. This is a square array of 64 (8x8) MEMS microphones which are spaced uniformly, every 2.125cm, in a rectangular Printed Circuit Board (PCB), with square gaps between the acoustic sensors, as it can be observed in Figure 2, in order to make the array as light and portable as possible.

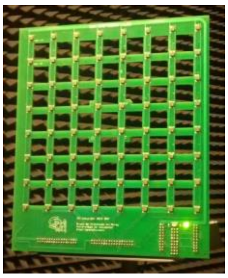

Fig. 2. Array of MEMS microphones.

This array was designed to work in an acoustic frequency range between 4 and 16kHz. The 2.125cm spacing corresponds to λ/2 for the 8kHz frequency.

5. Array acoustic characterization

A reference loudspeaker placed in different positions was employed to obtain the beampatterns of the MEMS array included in the system. Beamforming was carried out with a wideband FFT algorithm, focused on the loudspeaker position. Figure 3 shows one of the obtained beampatterns.

The measured beampatterns are very similar to the theoretical ones, which assume that the acoustic sensors are omnidirectional and paired in phase. Nevertheless, a more detailed analysis of the measured beampatterns shows: i) there are more sidelobes with a level higher than -20dB, and ii) there is a very small displacement of the sidelobes, which are closer. These effects are due to the fact that the gain of each microphone is slightly different for each frequency, as shown in Figure 1. This is the same effect as applying windowing techniques to the beamforming weight vector, which modifies the level and the position of the sidelobes.

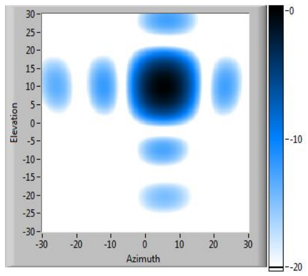

Fig. 3. Measured beampatterns for 16kHz and steering angles [azimuth, elevation]:[5º, 10º].

6. Conclusions

The averaged frequency responses of the MEMS microphones which have been employed to form the array are essentially flat, with a slight increase at high frequencies, and vary in a range of ± 2dB around the averaged value.

Analyzing the acoustic array characterization it was observed that as the variations of the measured beampattern, with respect to the theoretical one, are limited, it is not necessary to apply calibration techniques to the array.

Acknowledgements

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References

[1]. Van Trees, H. Optimum Array Processing: Part IV of Detection, Estimation and Modulation Theory, John Wiley & Sons: New York, USA, 2002.

[2]. Brandstein M.; Ward D., Microphone arrays, Springer: New York, USA, 2001.

[3]. del Val, L.; Jiménez, M.; Izquierdo, A.; Villacorta J. Optimisation of sensor positions in random linear arrays based on statistical relations between geometry and performance, Appl Acoust, 2012, 73 (1), pp. 78–82, DOI: 10.1016/j.apacoust.2011.07.002.

[4]. Hsieh, C.T.; Singapore, Y.; et al. The introduction of MEMS packaging technology, In Proceedings of 4th International Symposium on Electronic, Materials and Packaging, Kaohsiung, Taiwan, Dec. 4-6, 2002, pp. 300-306.

[5]. Beeby, S.; Ensell, G.; Kraft, M.; White, N. MEMS Mechanical Sensors; Artech House Publishers: Norwood, MA, USA, 2004.