



Acoustics '17 Boston

Boston MA

25–29 June 2017

173rd Meeting of the Acoustical Society of America and the 8th Forum Acusticum



Characterization of a virtual array based on MEMS microphones for the analysis of acoustic sources

Authors: Alberto Izquierdo

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Contents

- Introduction
- Material and Methods
- Results
- Conclusions



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Introduction

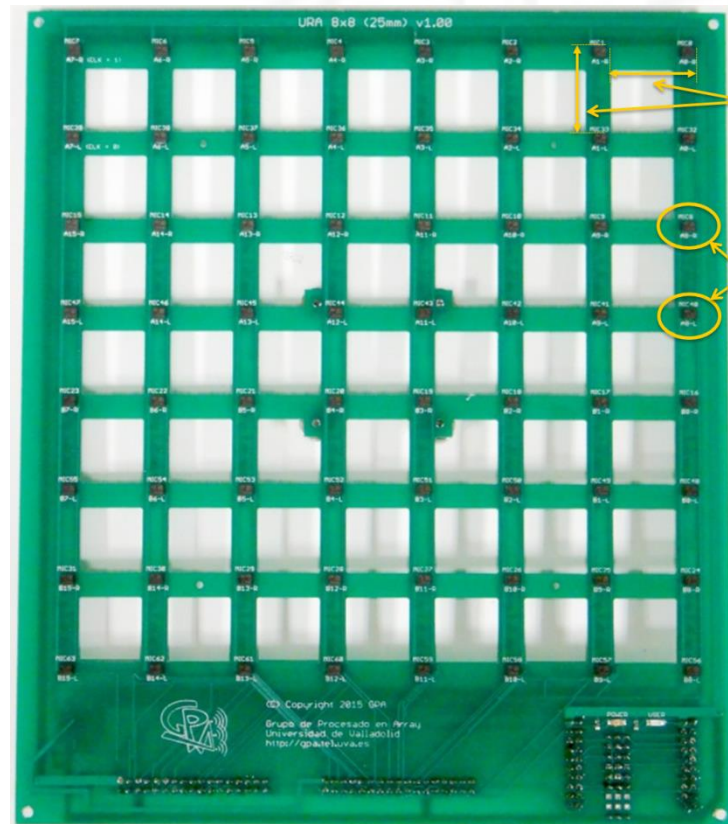
- Introduction
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- Development of **acoustic imaging** techniques using **microphone arrays** → Many applications
- **Machinery** acoustic imaging high dependence of industrial plants reverberation → Large arrays
- Use of **arrays of MEMS microphones** allows low-cost systems with hundreds of sensors
- **Problem:** Some applications need high number of sensors → too expensive systems
- **Solution: Virtual arrays**



- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones

Working frequency range: 40Hz – 16kHz



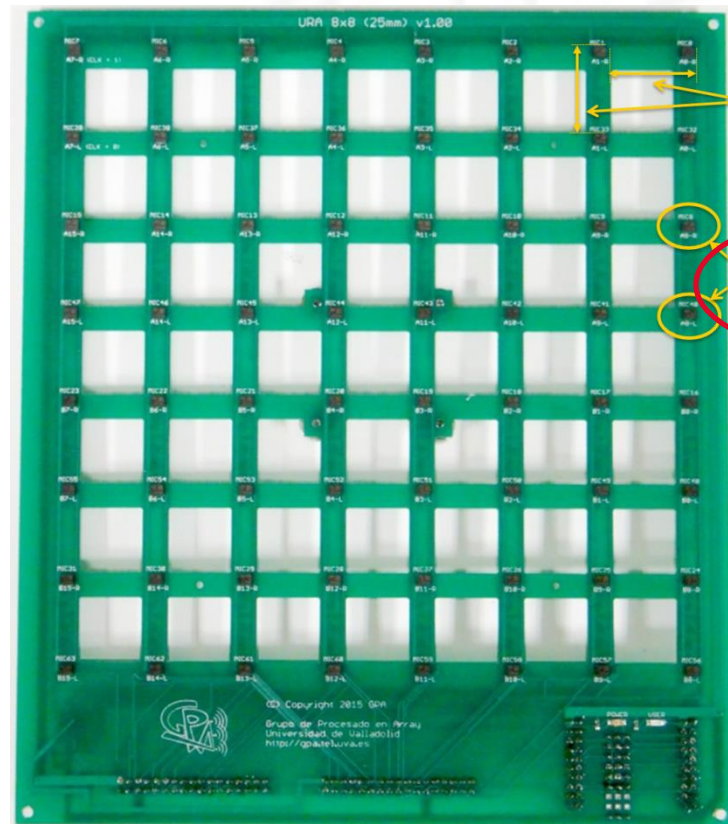
2.125 cm
sensor spacing

64 MEMS
microphones

- MP34DT01
STMicroelectronics
- PDM interface
 - Low-power
 - Omnidirectional
 - 63dB SNR
 - High sensibility

- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones

Working frequency range: 40Hz – 16kHz



2.125 cm
sensor spacing

8x8 grid

64 MEMS
microphones

MP34DT01

STMicroelectronics

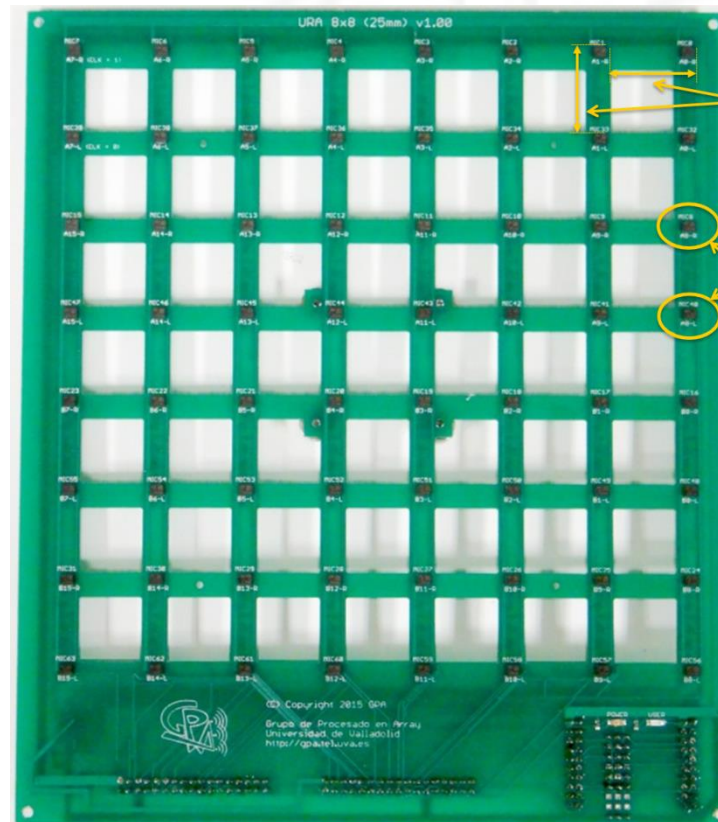
- PDM interface
- Low-power
- Omnidirectional
- 63dB SNR
- High sensibility

- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones

Working frequency range: 40Hz – 16kHz



$$2.125\text{cm} = 8\text{kHz } \lambda/2$$



2.125 cm sensor spacing

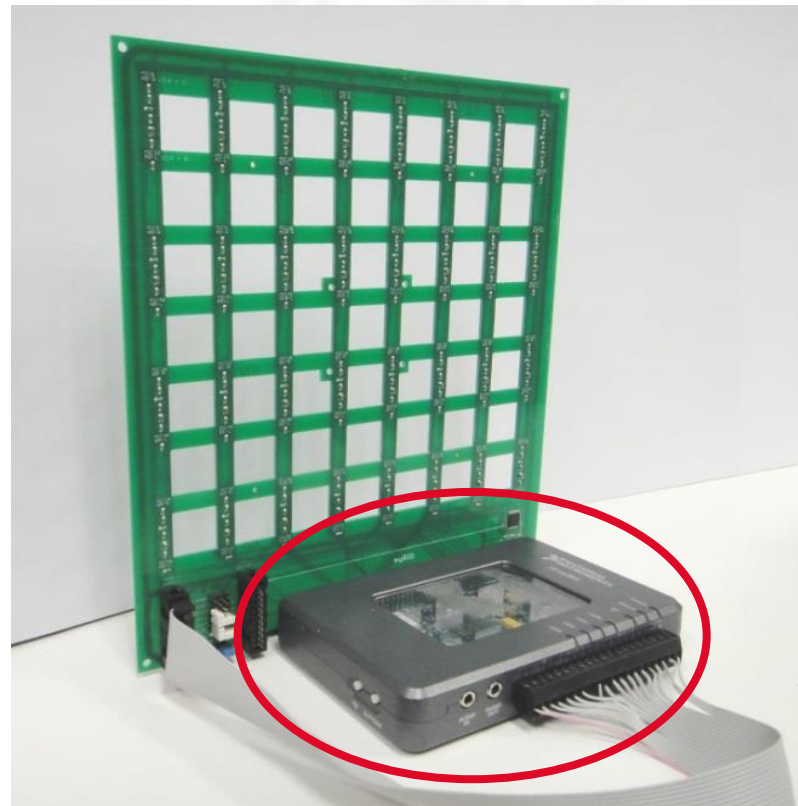
64 MEMS microphones

- MP34DT01
STMicroelectronics
- PDM interface
 - Low-power
 - Omnidirectional
 - 63dB SNR
 - High sensibility

Material and Methods

- Introduction
- **Material and methods**
- Results
- Conclusions

- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones
 - **myRIO** platform, base unit of the system



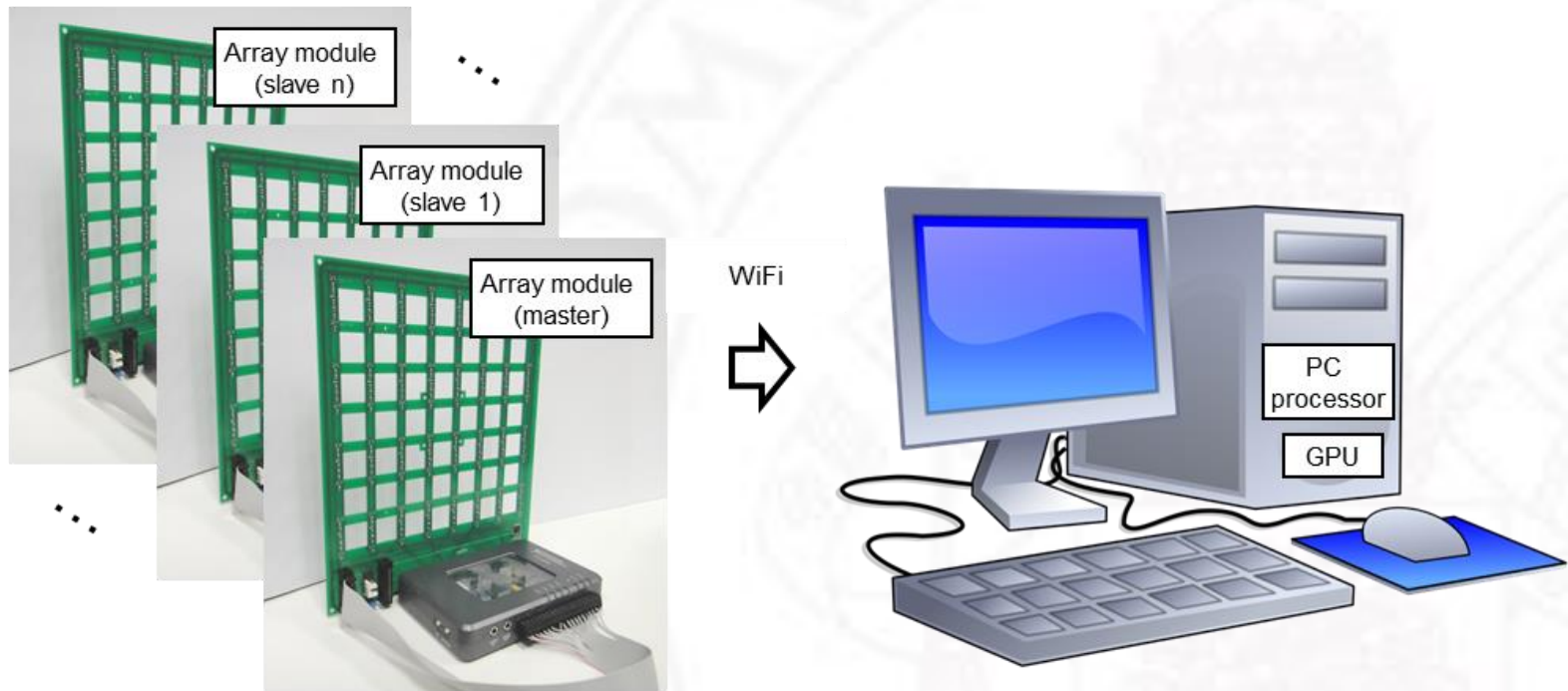
FPGA-based



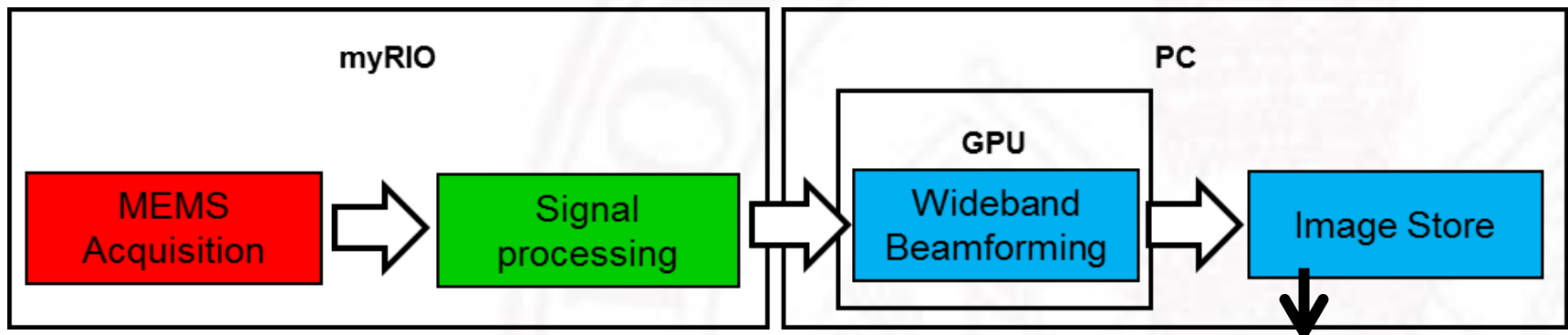
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- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones
 - **myRIO** platform, base unit of the system



- Acoustic images acquisition system:
 - **Array** of digital **MEMS** microphones
 - **myRIO** platform, base unit of the system
 - **Processing platform**



4D acoustic images:

- Azimuth
- Elevation
- Range
- Frequency

Material and Methods

- Introduction
- **Material and methods**
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- **3D positioning system:**
 - Array positioning inside a $1500 \times 1500 \times 1500 \text{ mm}^3$ volume
 - Repeatability accuracy each dimension: 0.02 mm

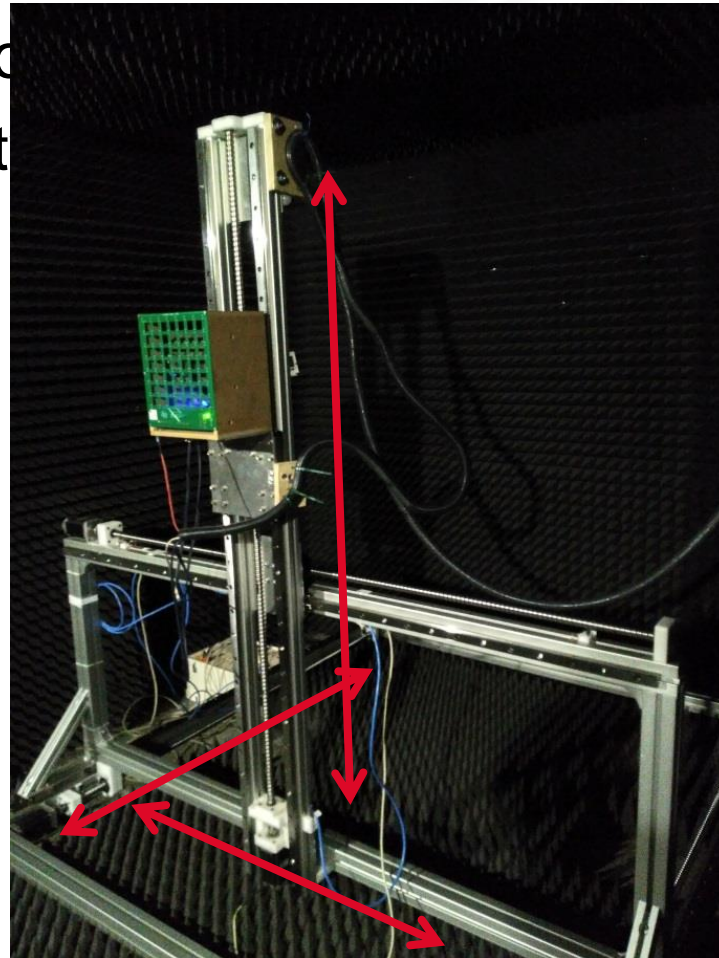


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- **3D positioning system:**

- Array positioned in a 1500mm^3 volume
- Repeatability: 0.02 mm



Material and Methods

- **Virtual array philosophy:**

- Position of 8x8 MEMS array is changed on vertical and horizontal directions with positioning system, in steps:
 - Odd steps: 1.0625 cm ($= 2.125/2$, 2.125cm: sensor spacing)
 - Even steps: 17 cm ($= 2.125*8$, 8x8 array spatial aperture)
- 80x80 MEMS array with 1.0625cm sensor spacing



Material and Methods

- Introduction
- **Material and methods**
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- **Virtual**

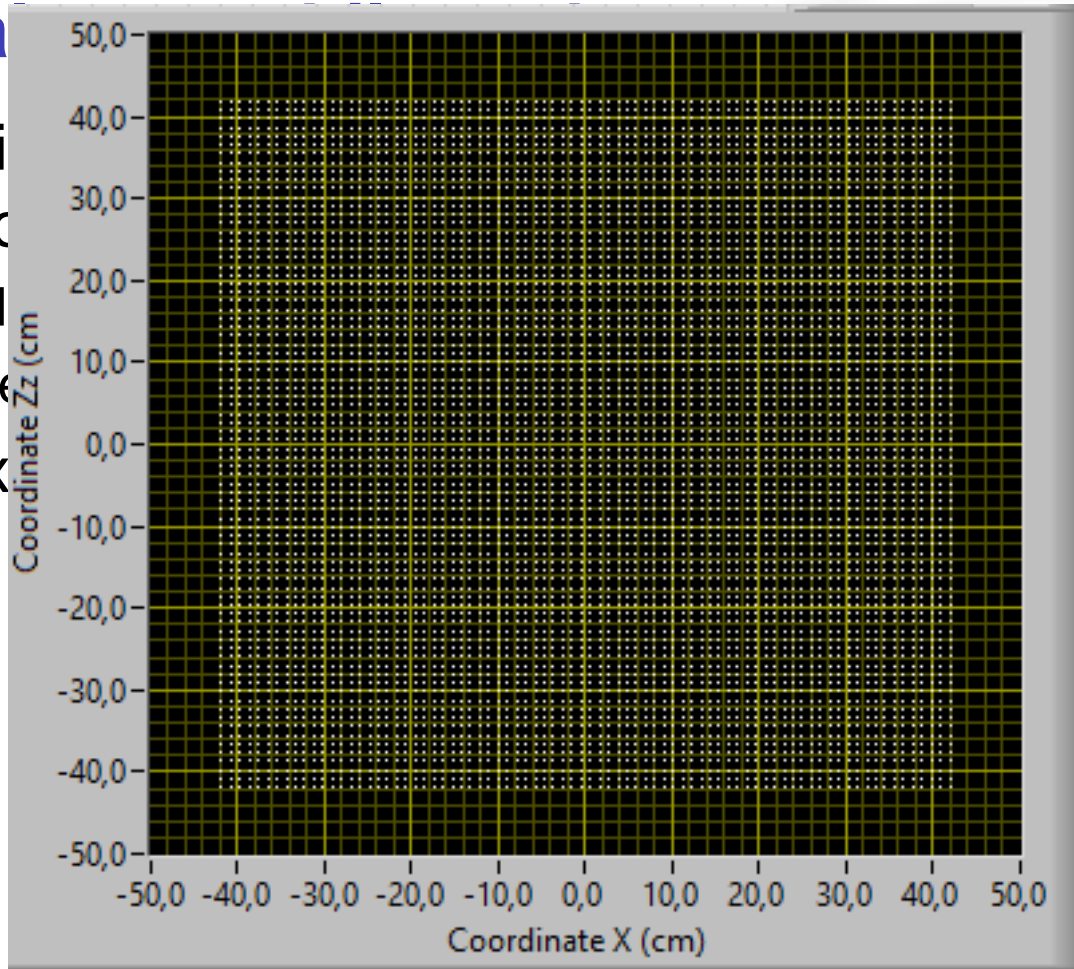
- Position

- horizontal

- Odd

- Even

- 80x



vertical and

, in steps:

(or spacing)

(aperture)

spacing



Material and Methods

- **Virtual array philosophy:**

- Position of 8x8 MEMS array is changed on vertical and horizontal directions with positioning system, in steps:

- Odd steps: 1.0625 cm ($= 2.125/2$, 2.125cm: sensor spacing)
- Even steps: 17 cm ($= 2.125*8$, 8x8 array spatial aperture)

- 80x80 MEMS array with 1.0625cm sensor spacing

- Addition of data acquired by 8x8 array in each position to a data structure equivalent to the one of a 80x80 array.



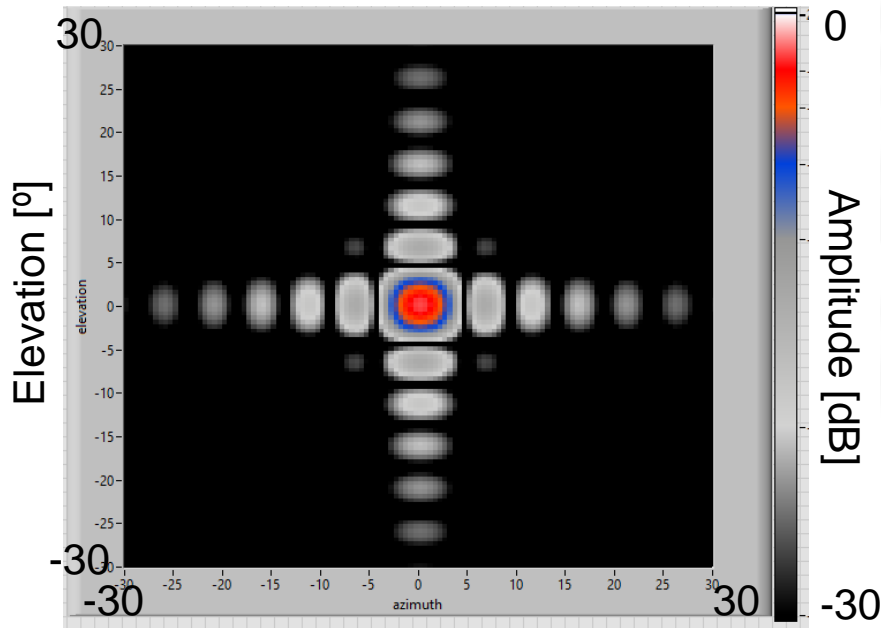
- **Virtual array philosophy:**

- Position of 8x8 MEMS array is changed on vertical and horizontal directions with positioning system, in steps:
 - Odd steps: 1.0625 cm ($= 2.125/2$, 2.125cm: sensor spacing)
 - Even steps: 17 cm ($= 2.125*8$, 8x8 array spatial aperture)
- 80x80 MEMS array with 1.0625cm sensor spacing
- Addition of data acquired by 8x8 array in each position to a data structure equivalent to the one of a 80x80 array.
- Beamforming techniques over the whole data
 - Obtaining high resolution acoustic images

Results

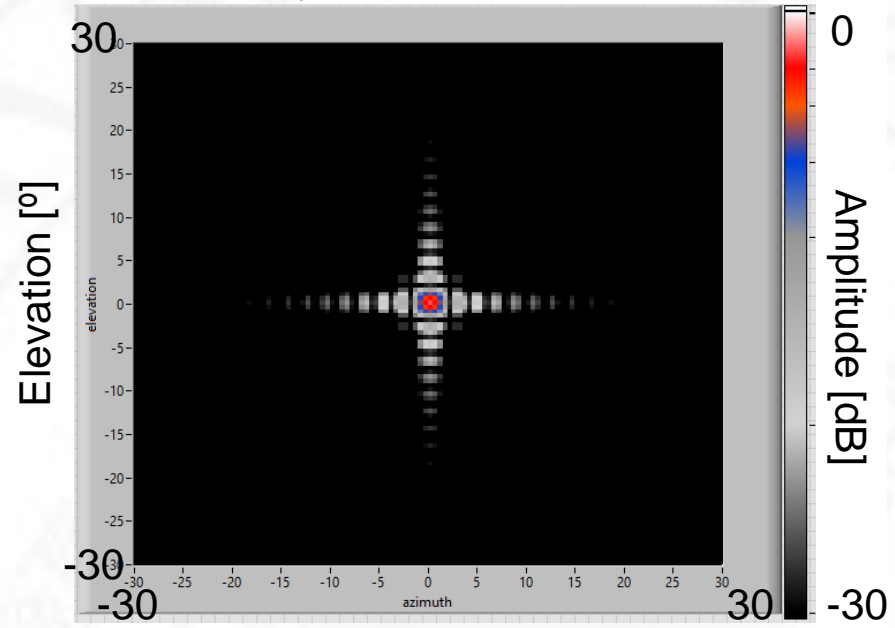
- 80x80 array **theoretical beampattern:**

Frequency: 500 Hz



Azimuth [°]

Frequency: 1200 Hz

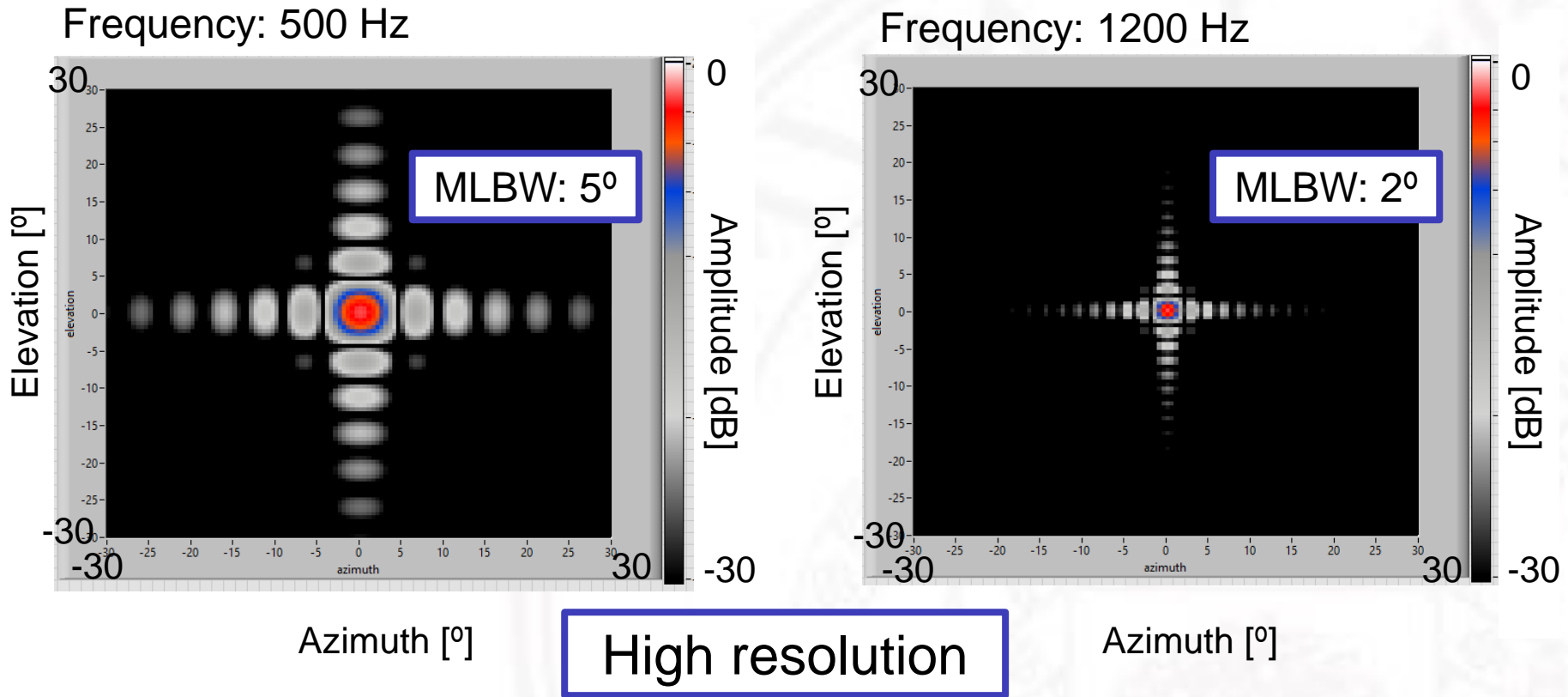


Azimuth [°]

Results

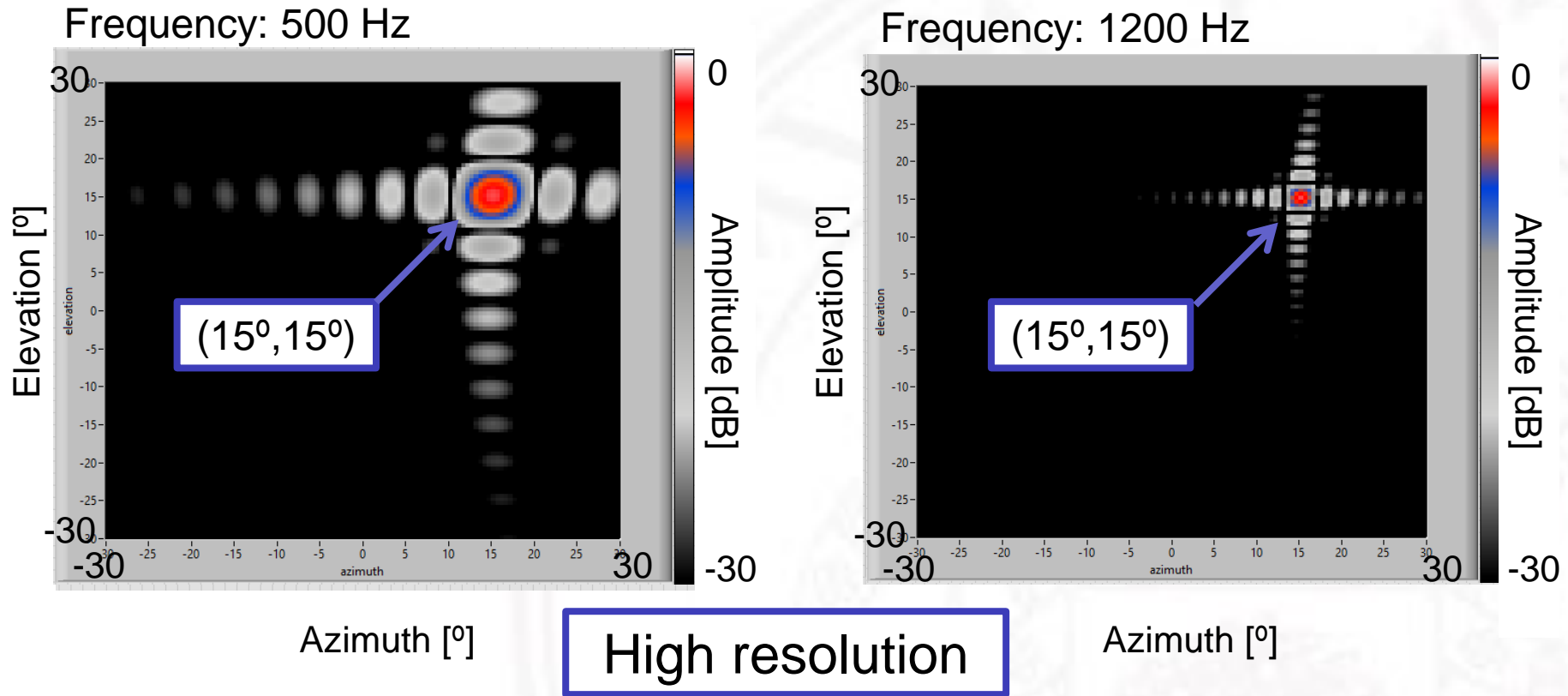
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- 80x80 array **theoretical beampattern:**



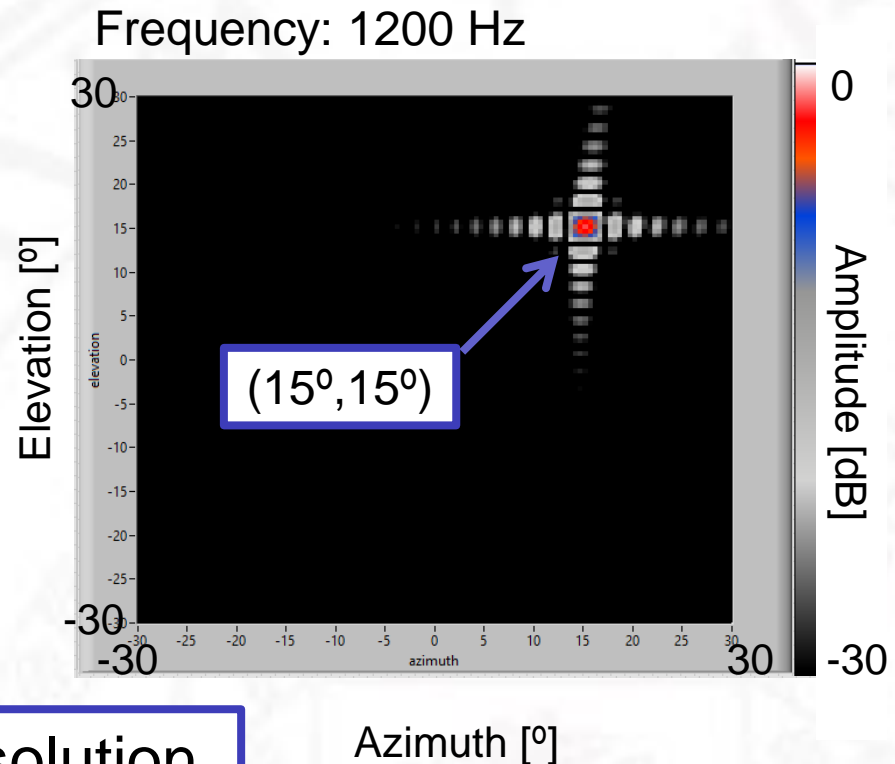
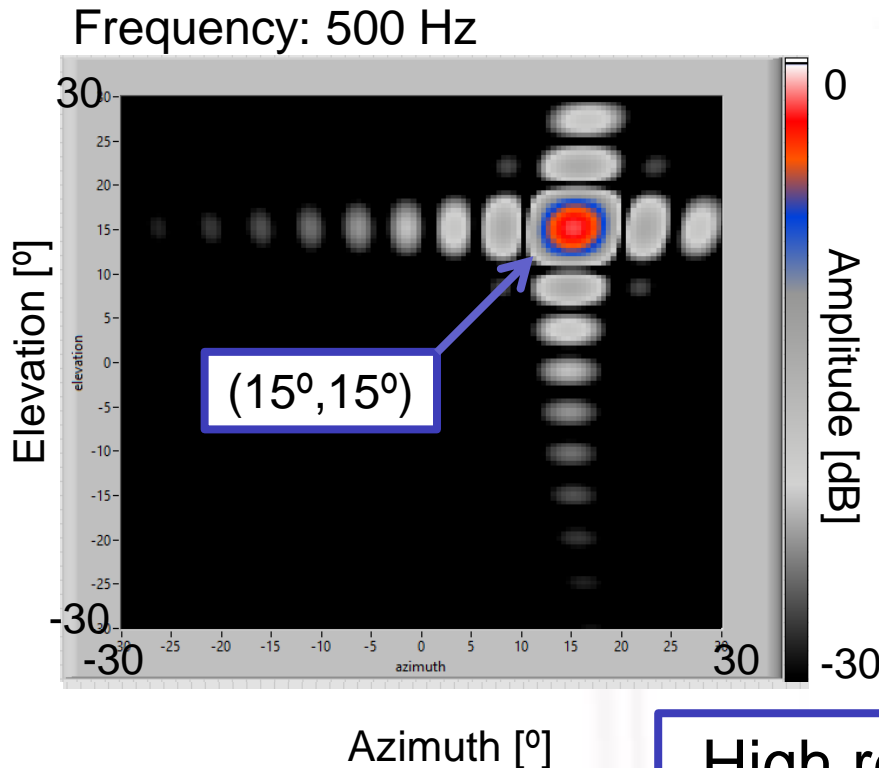
Results

- 80x80 array **theoretical beampattern:**



Results

- 80x80 array **theoretical beampattern:**



High resolution

Spherical wave assumption

Results

- Introduction
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- Mannequin **acoustic images**:



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Results

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- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber

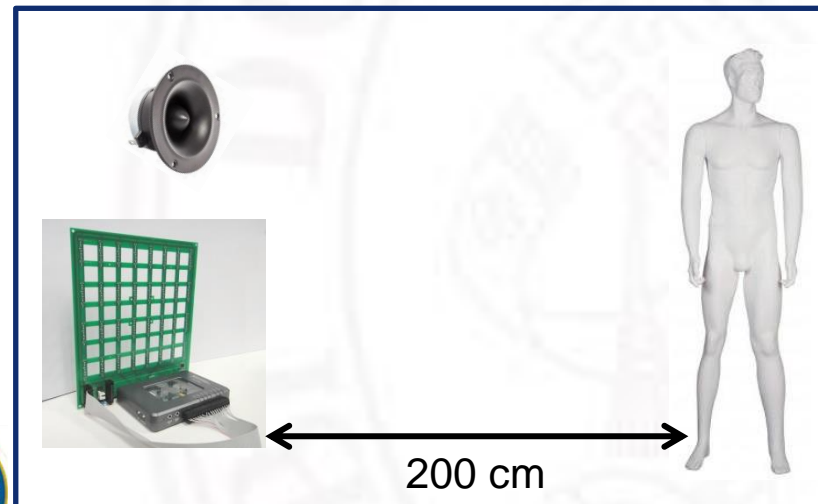


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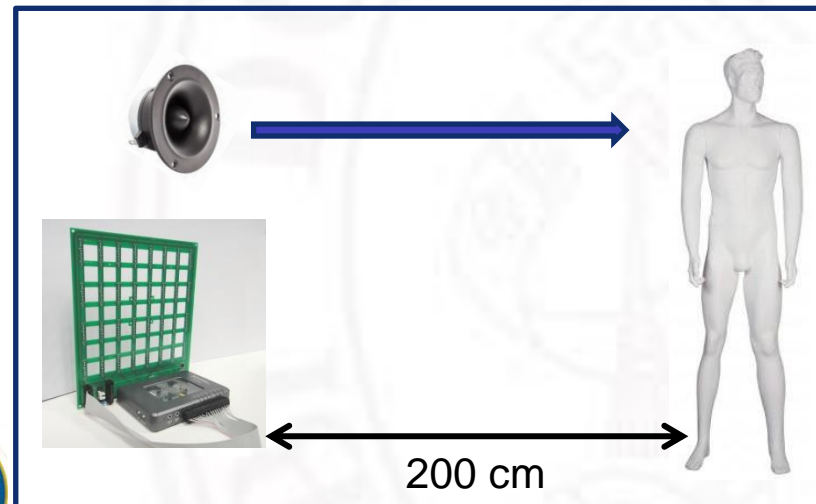
Results

- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber
 - **SODAR principle**



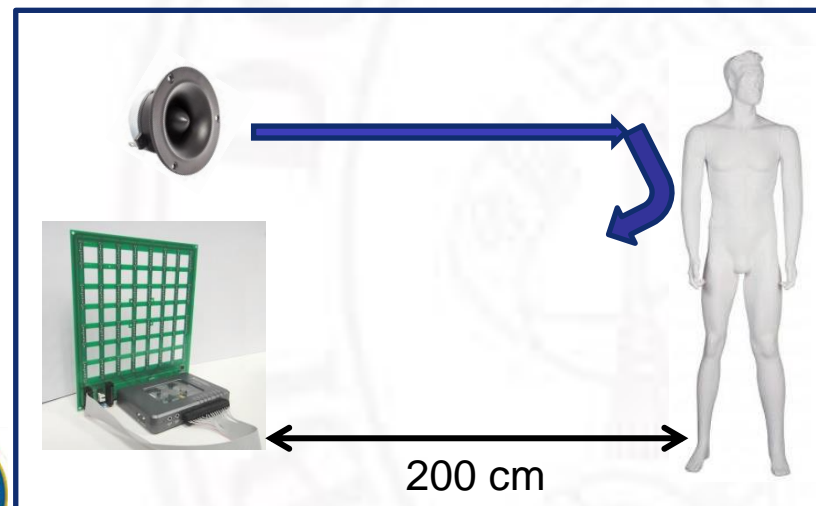
Results

- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber
 - **SODAR principle**
 - Tweeter generates multifreq. sound towards mannequin



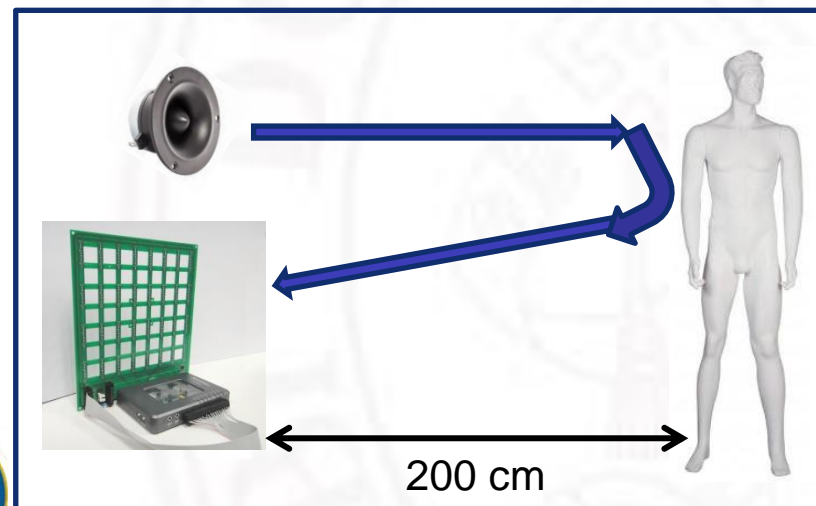
Results

- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber
 - **SODAR principle**
 - Tweeter generates multifreq. sound towards mannequin
 - Sound reflected over mannequin



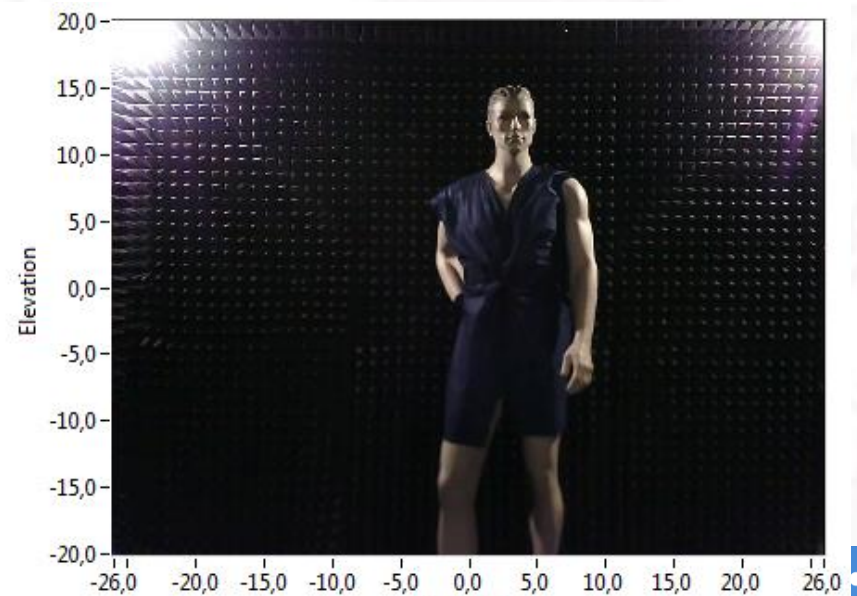
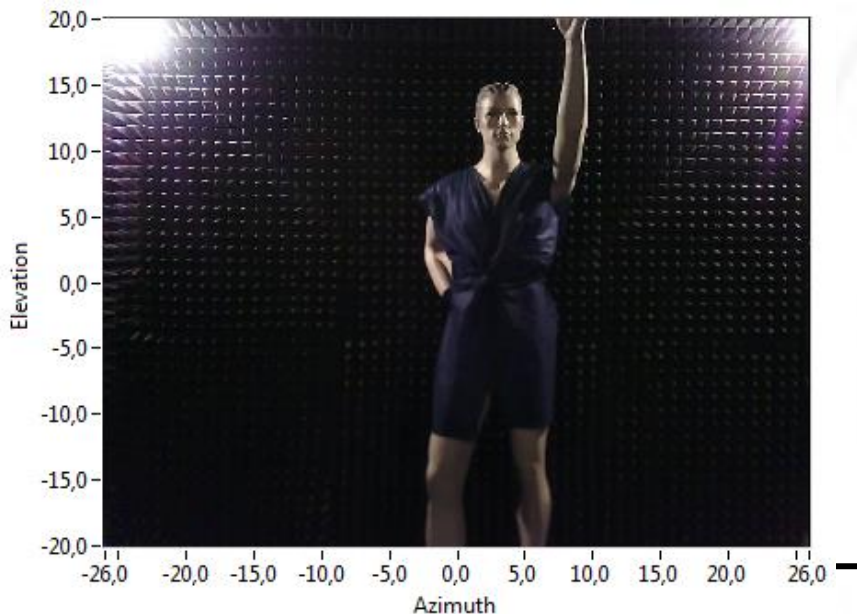
Results

- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber
 - **SODAR principle**
 - Tweeter generates multifreq. sound towards mannequin
 - Sound reflected over mannequin
 - Reflected sound received by the MEMS array



Results

- Mannequin **acoustic images**:
 - Tests inside an hemianechoic chamber
 - **SODAR principle**
 - Mannequin in two positions:



Results

- Introduction
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- Mannequin **acoustic images**:

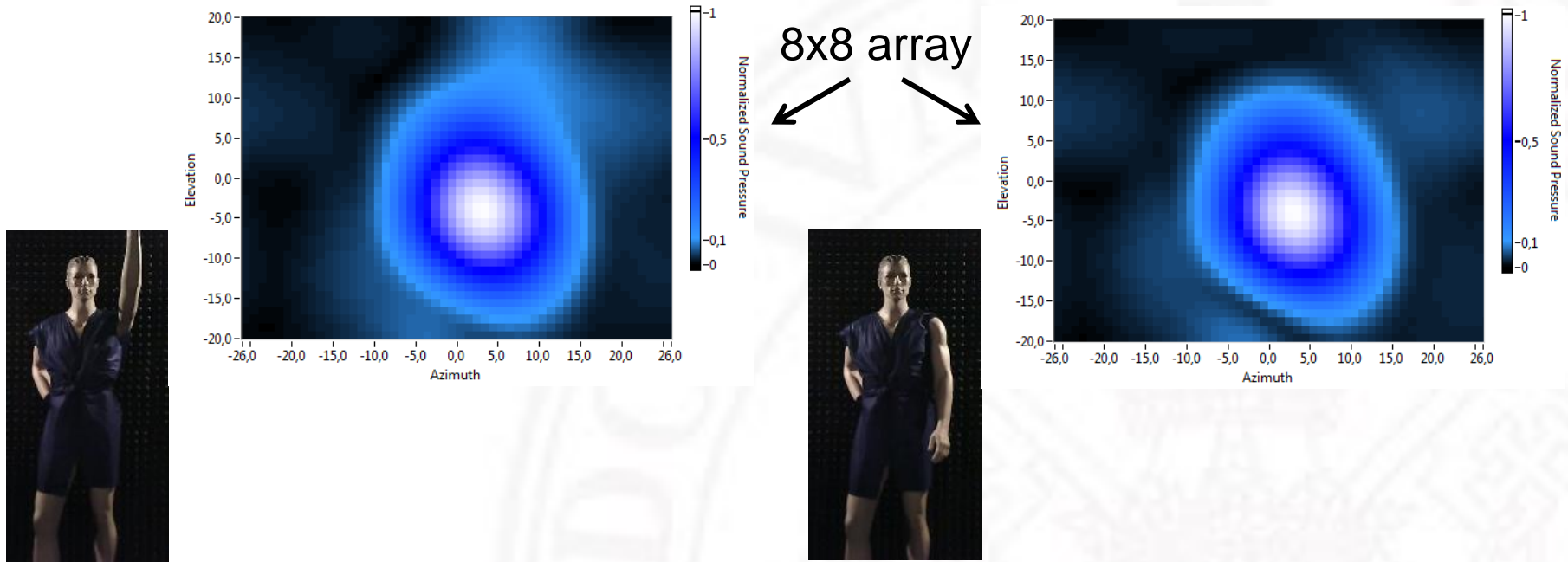
Frequency: 1500 Hz
Range: 240 cm



Results

- Mannequin **acoustic images**:

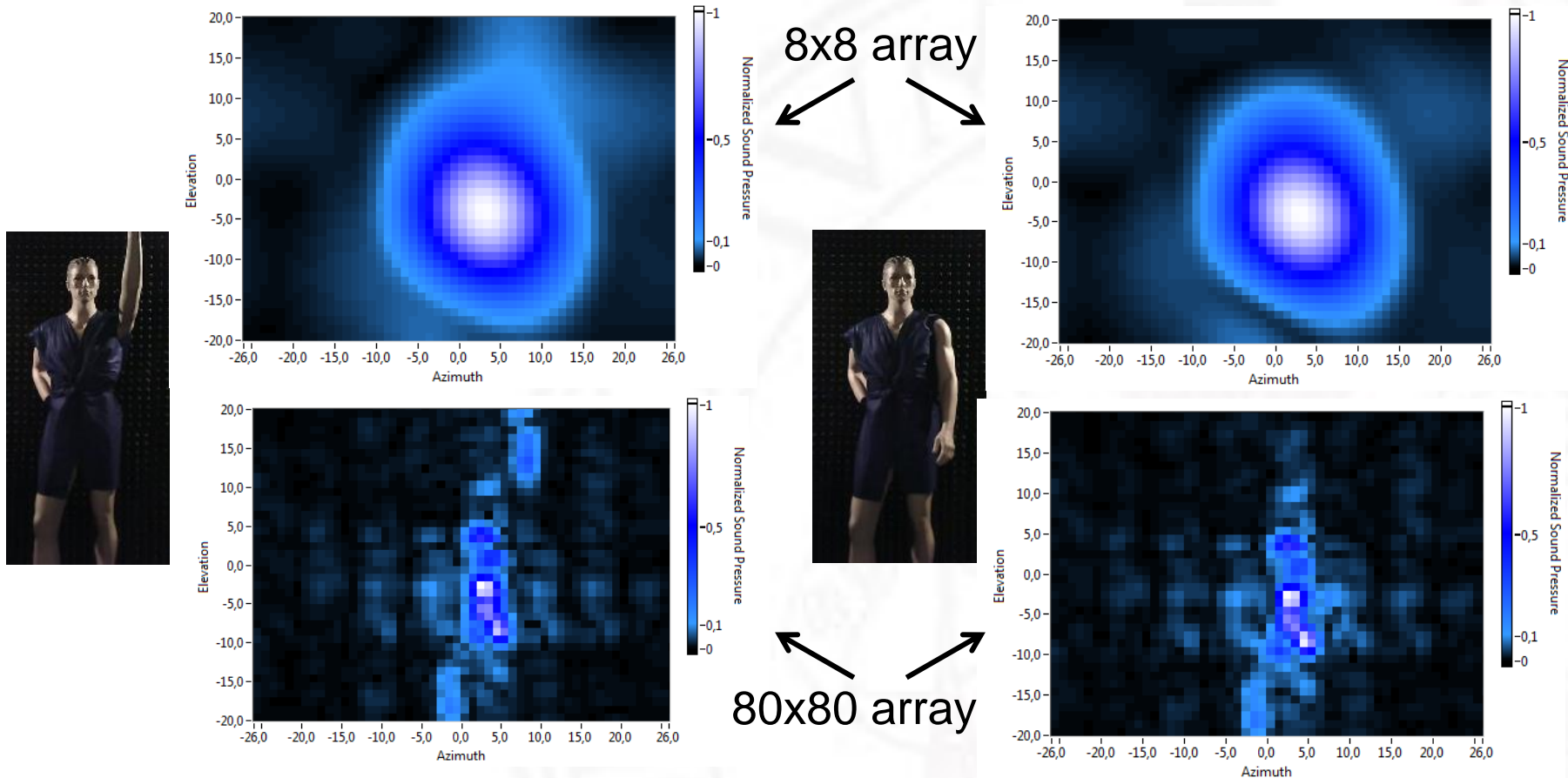
Frequency: 1500 Hz
Range: 240 cm



Results

- Mannequin **acoustic images**:

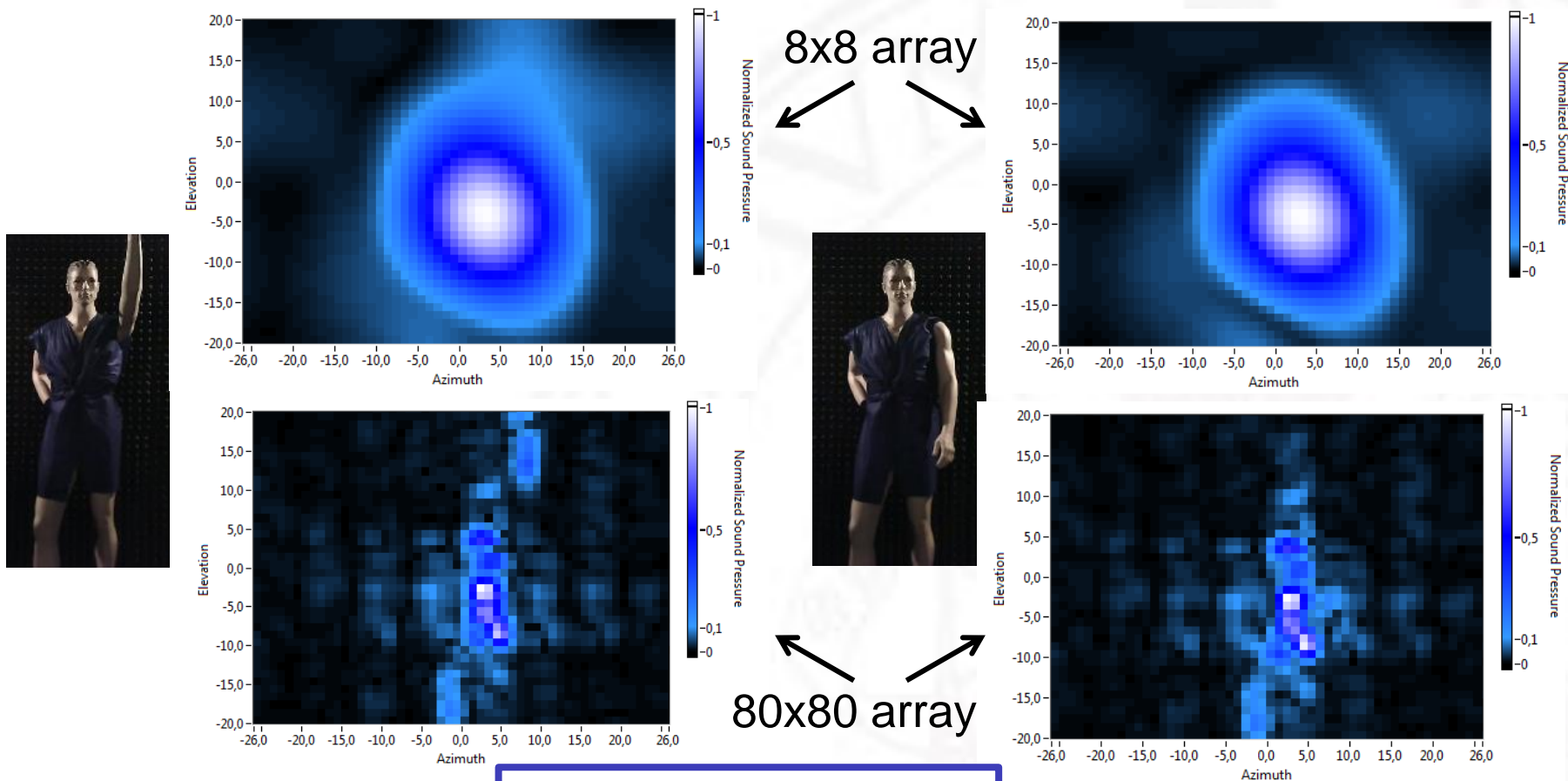
Frequency: 1500 Hz
Range: 240 cm



Results

- Mannequin **acoustic images**:

Frequency: 1500 Hz
Range: 240 cm

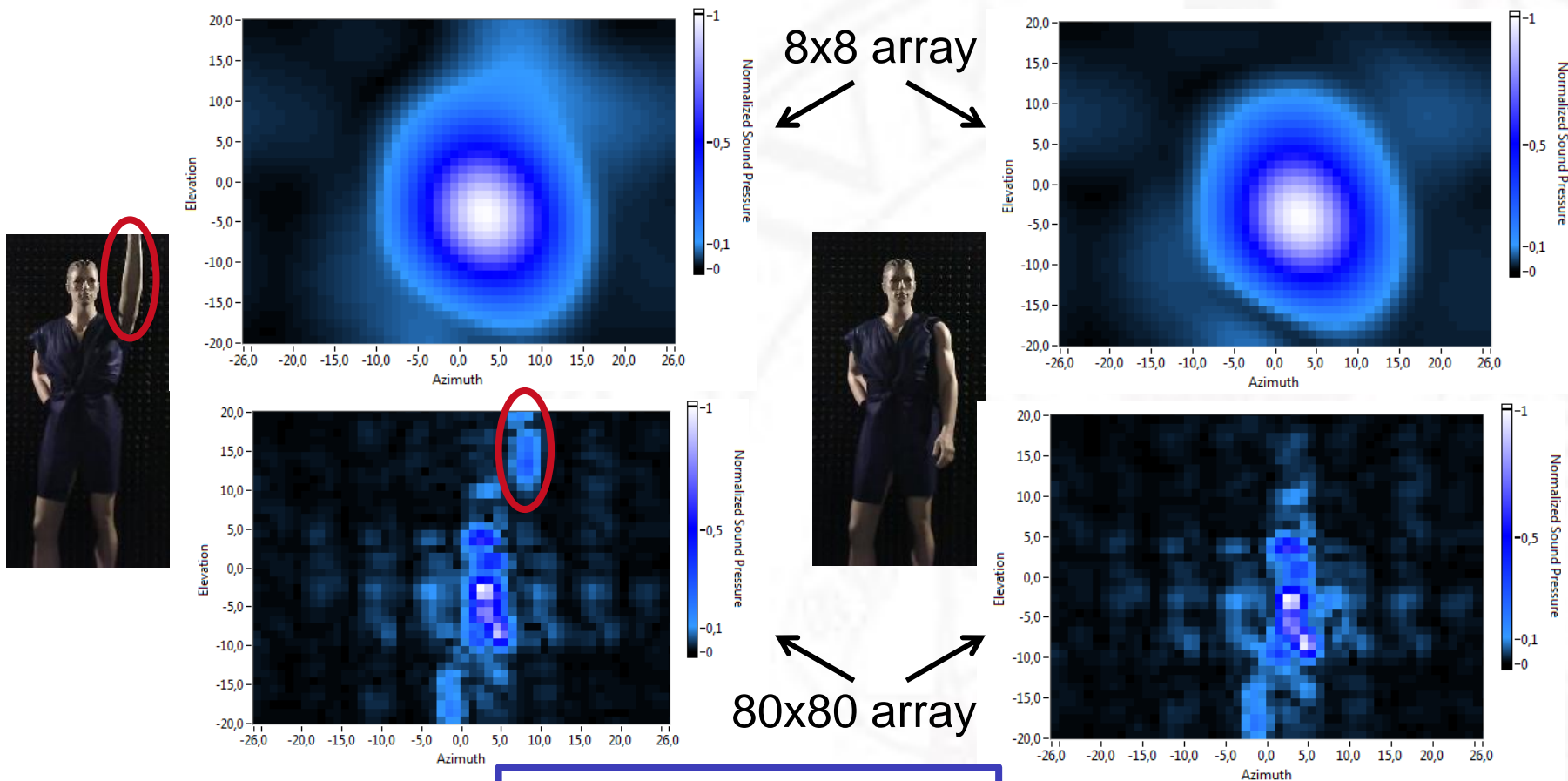


Higher resolution

Results

- Mannequin **acoustic images**:

Frequency: 1500 Hz
Range: 240 cm



Higher resolution

Results

- Introduction
- Material and methods
- **Results**
- Conclusions

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz

Frequency:



Range:



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Results

- Introduction
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- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz

Frequency:

↑ freq. → ↑ resolution

Range:



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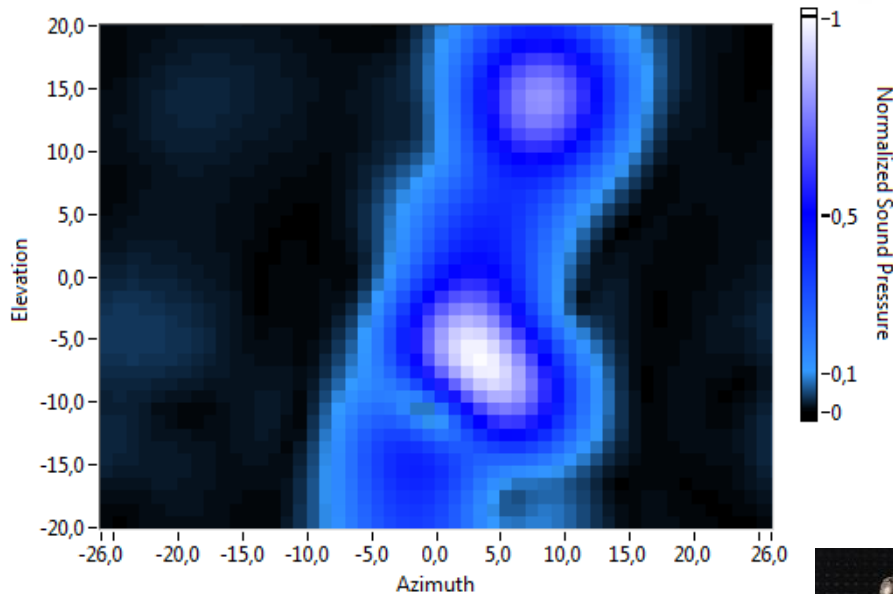


Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 550 Hz

Range:

↑ freq. → ↑ resolution

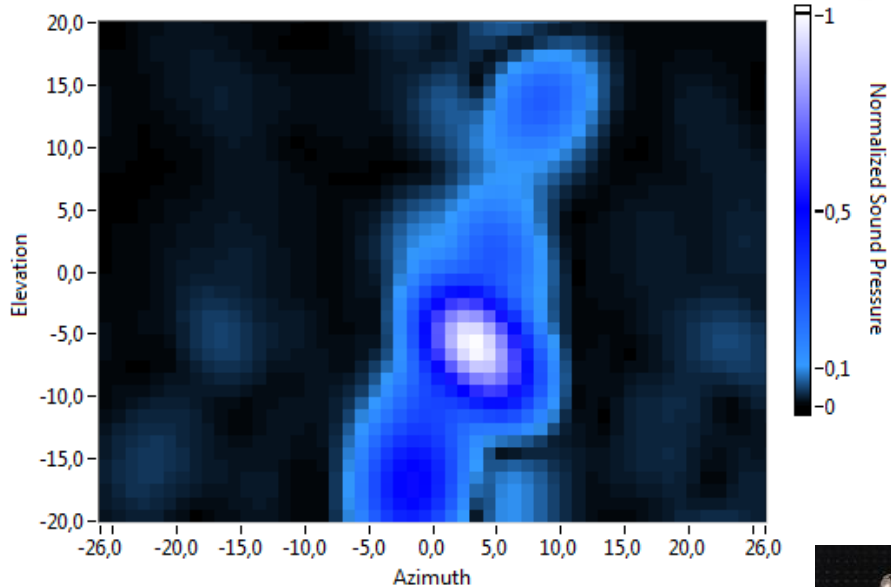


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Results

- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz

Frequency: 700 Hz

↑ freq. → ↑ resolution



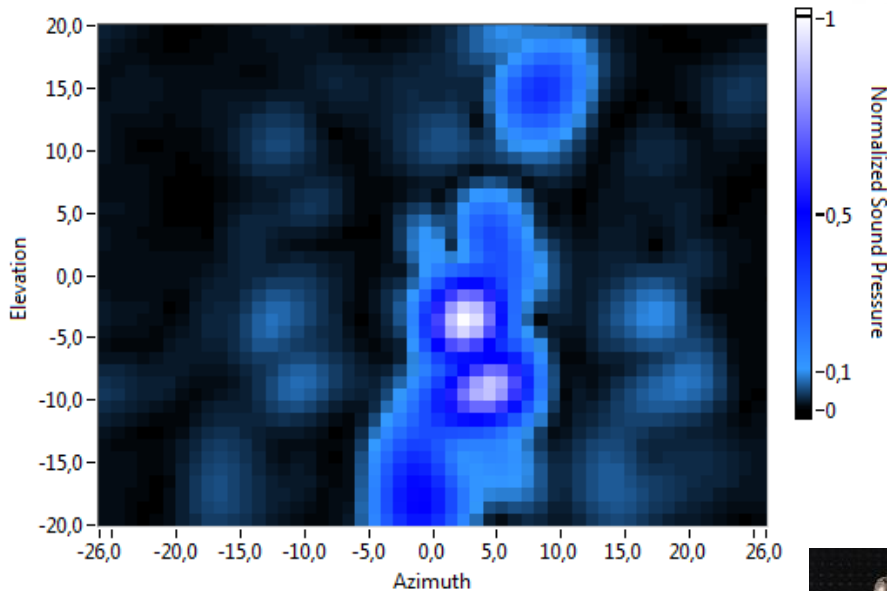
Range:

Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 850 Hz

Range:

↑ freq. → ↑ resolution

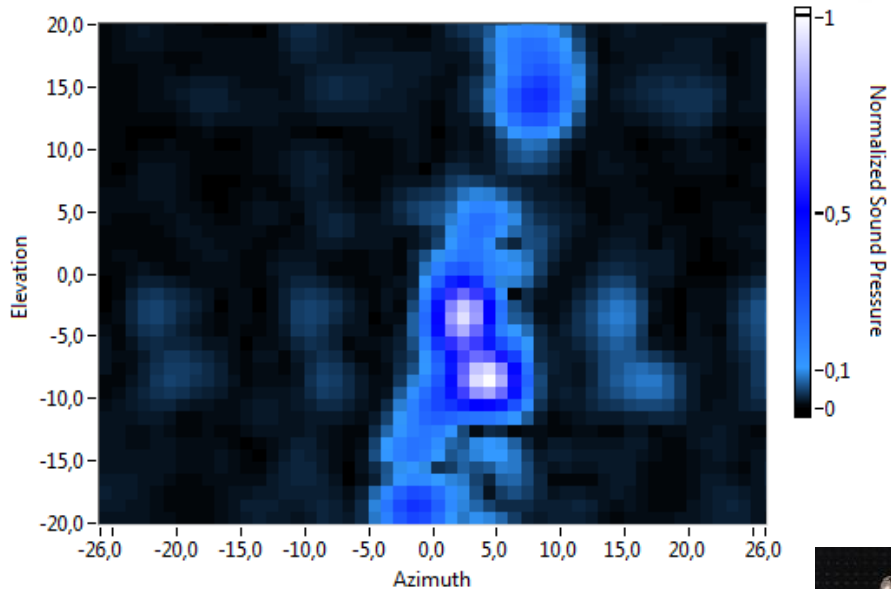


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Results

- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz

Frequency: 1000 Hz

↑ freq. → ↑ resolution



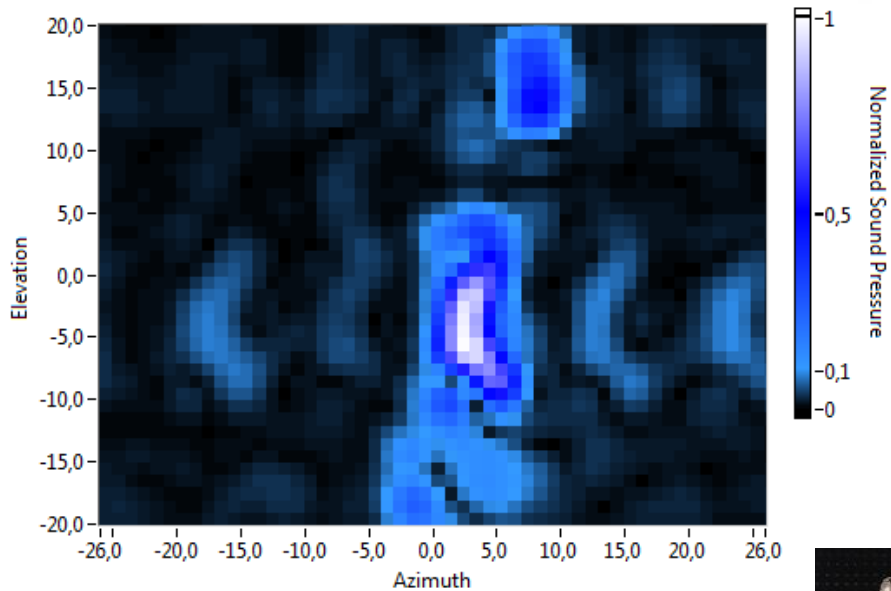
Range:

Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 1150 Hz

↑ freq. → ↑ resolution



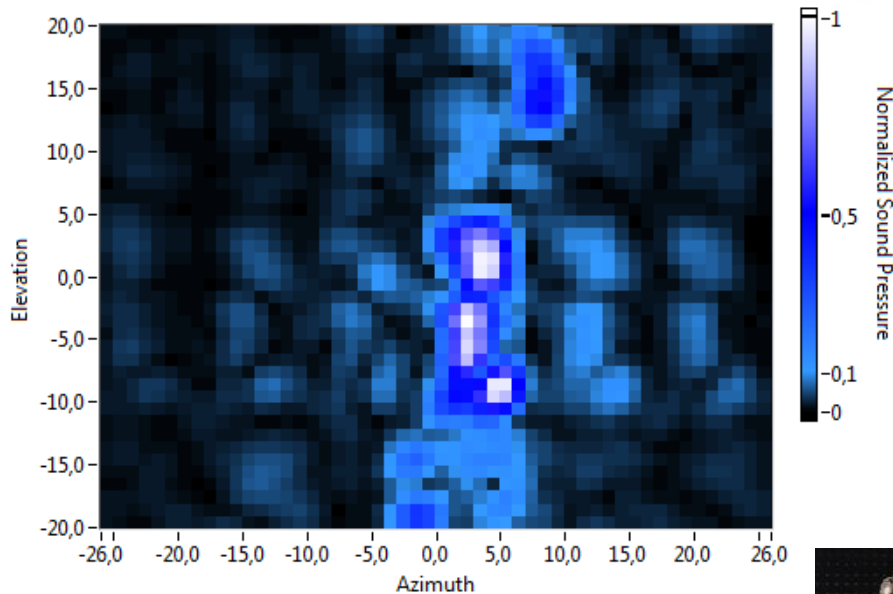
Range:

Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 1300 Hz

↑ freq. → ↑ resolution



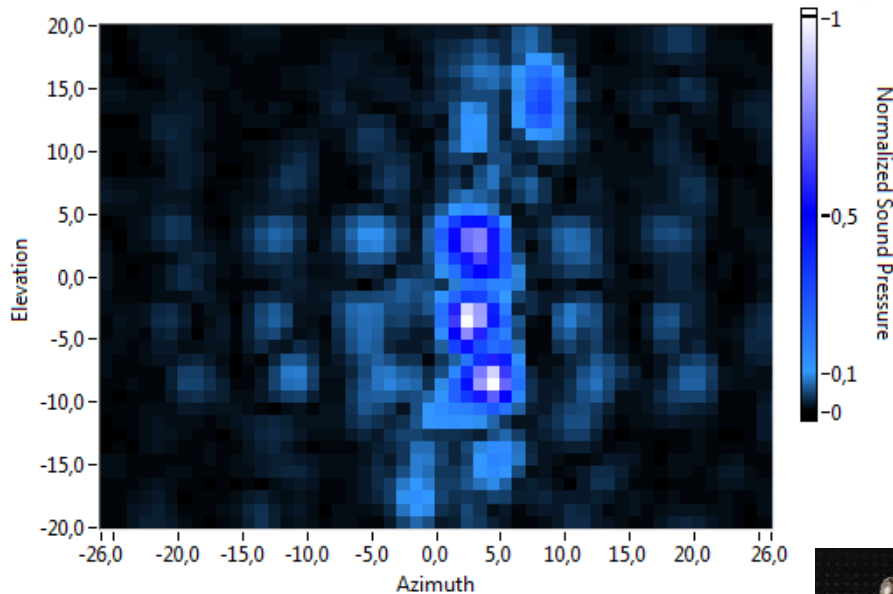
Range:

Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 1500 Hz

Range:

↑ freq. → ↑ resolution



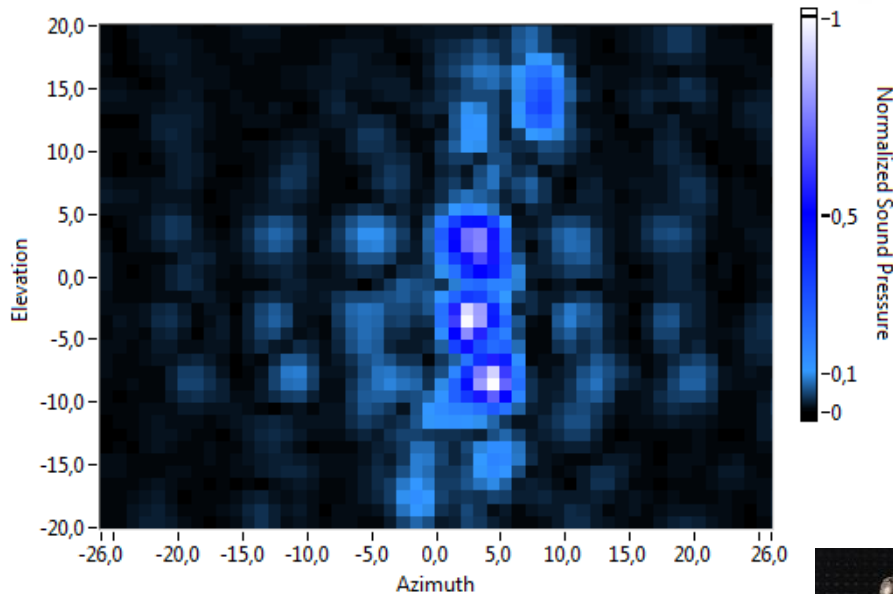
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Results

- Mannequin **acoustic images**:

Range: 240 cm

Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range:

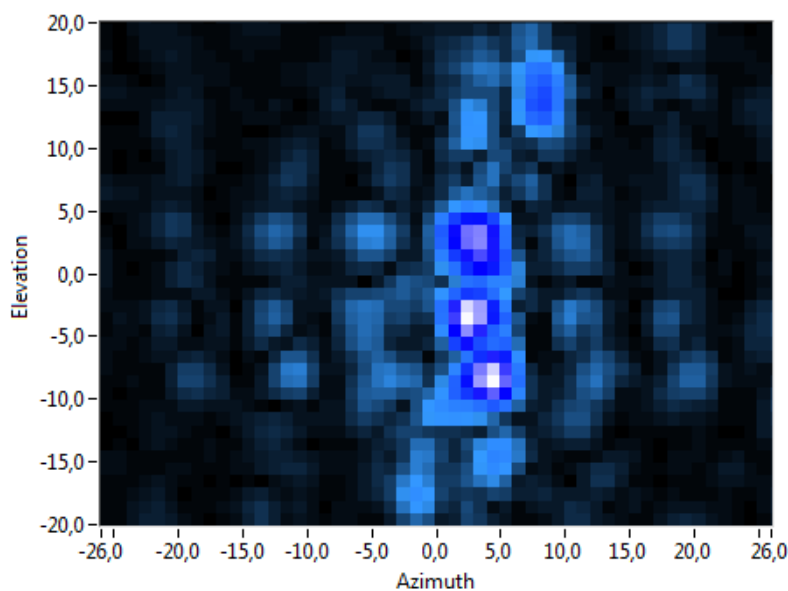
Body parts identification



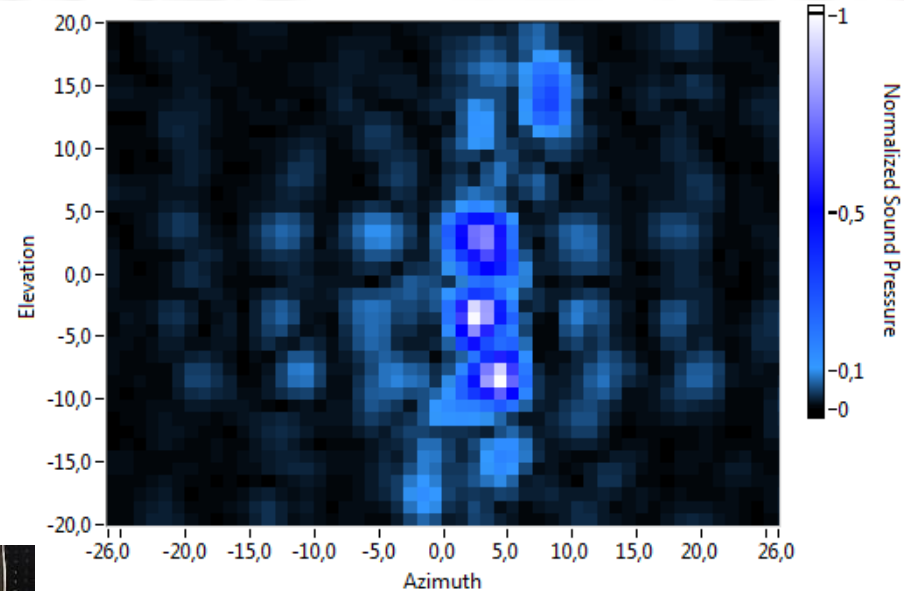
Results

- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range: 210 cm

Body parts identification

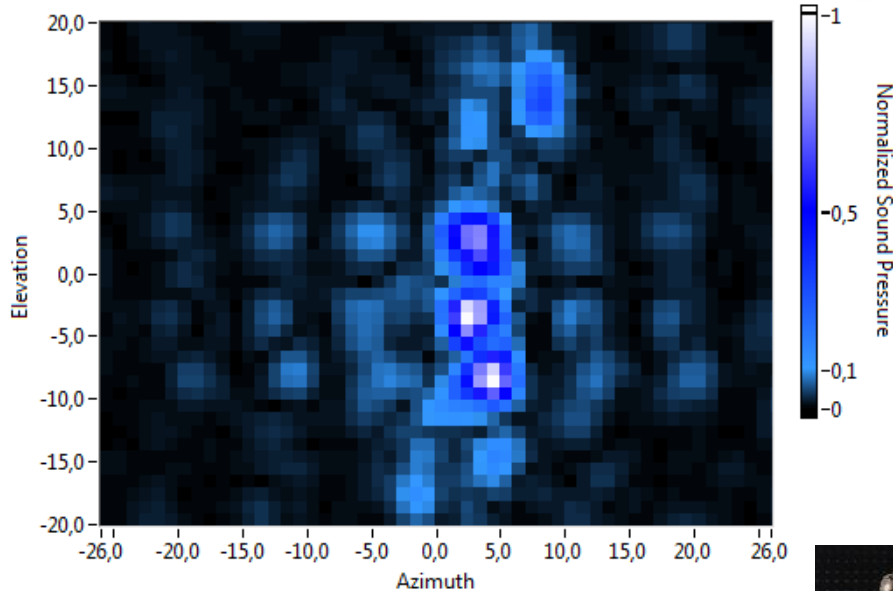


Results

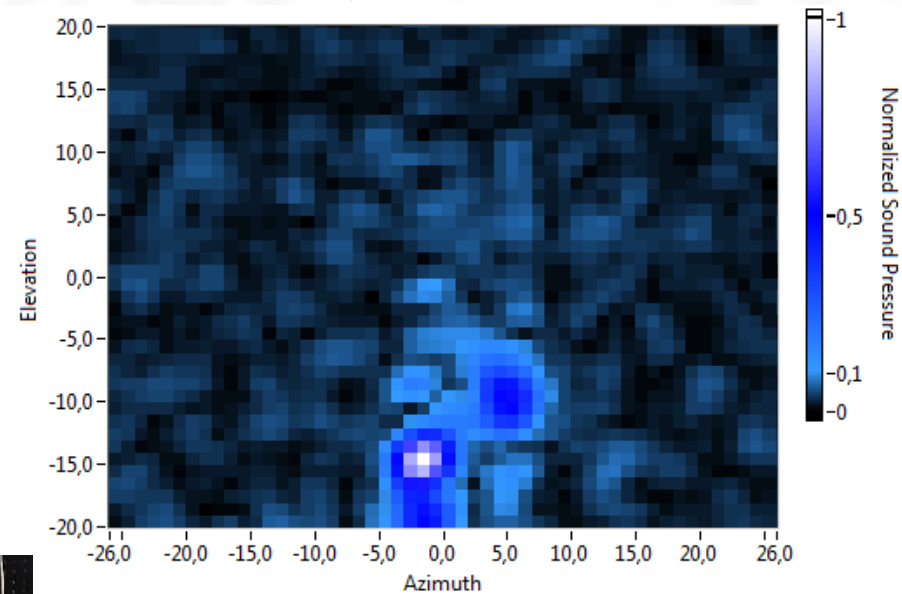
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- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution



Range: 220 cm

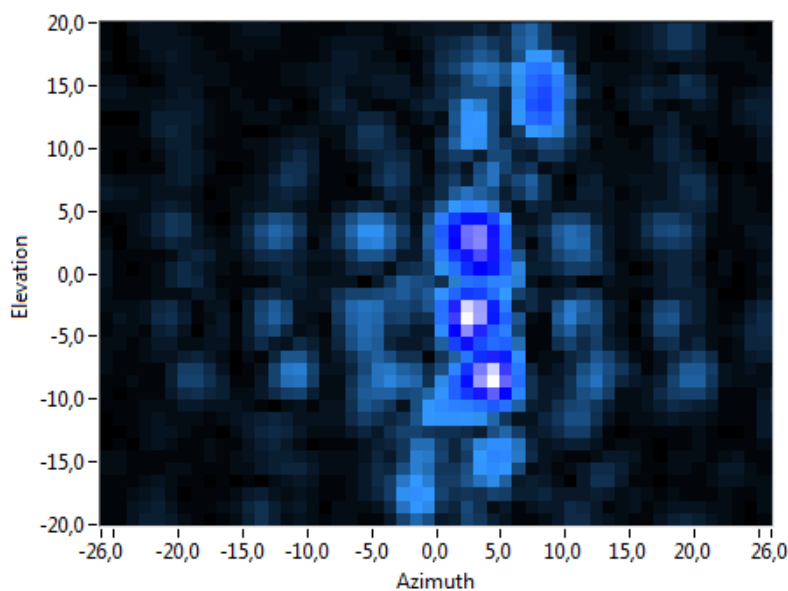
Body parts identification

Results

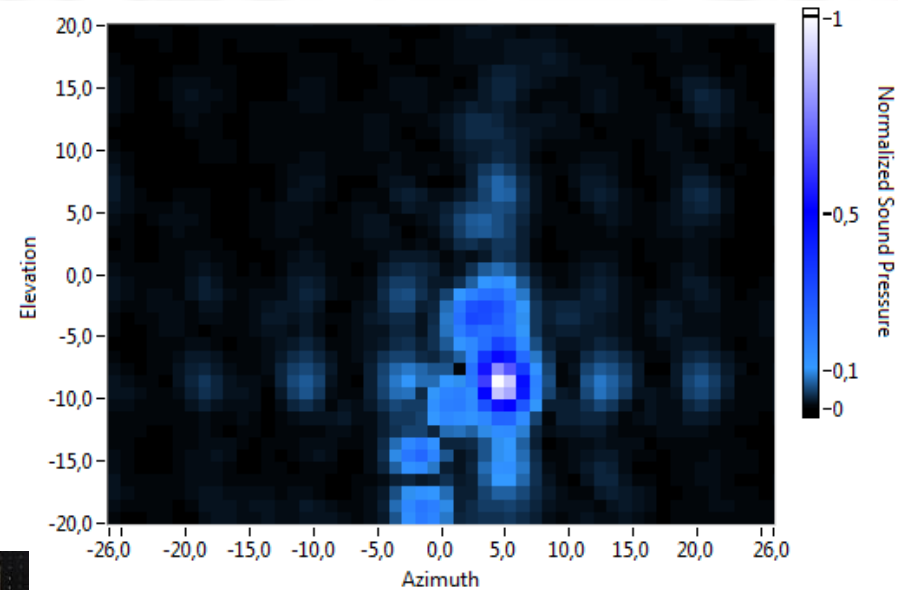
- Introduction
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- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range: 230 cm

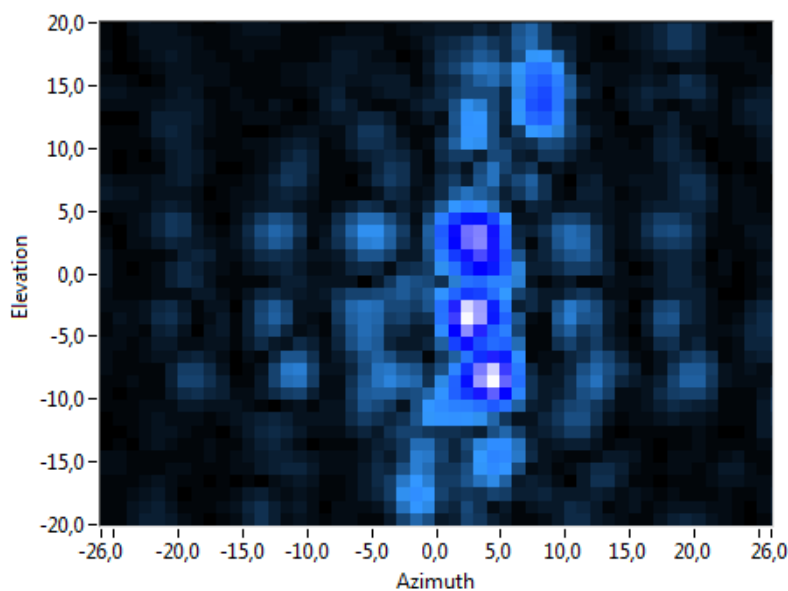
Body parts identification



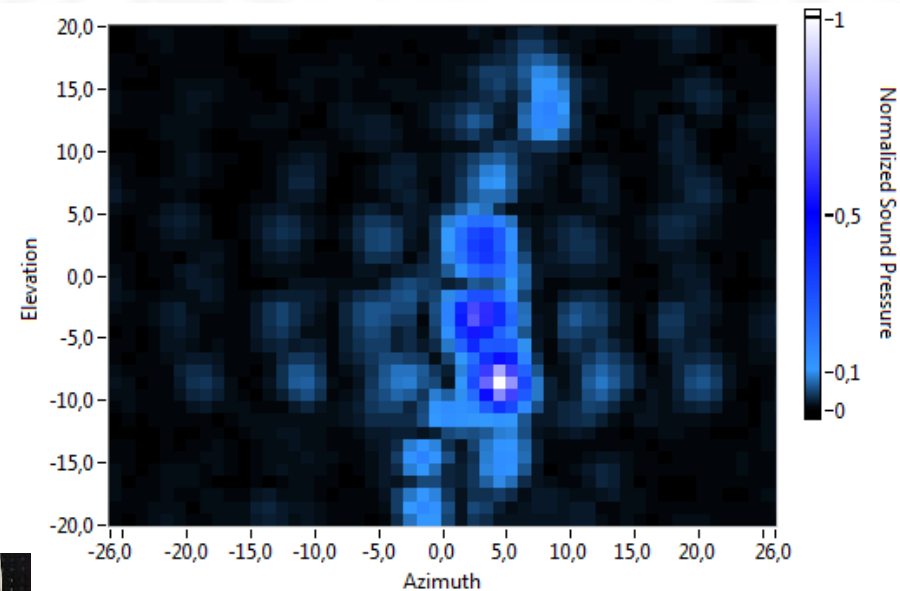
Results

- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range: 240 cm

Body parts identification

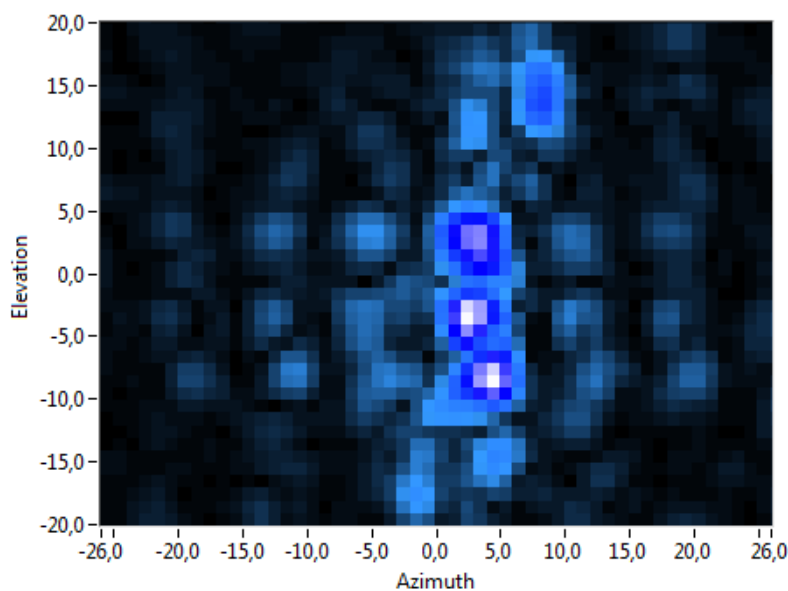


Results

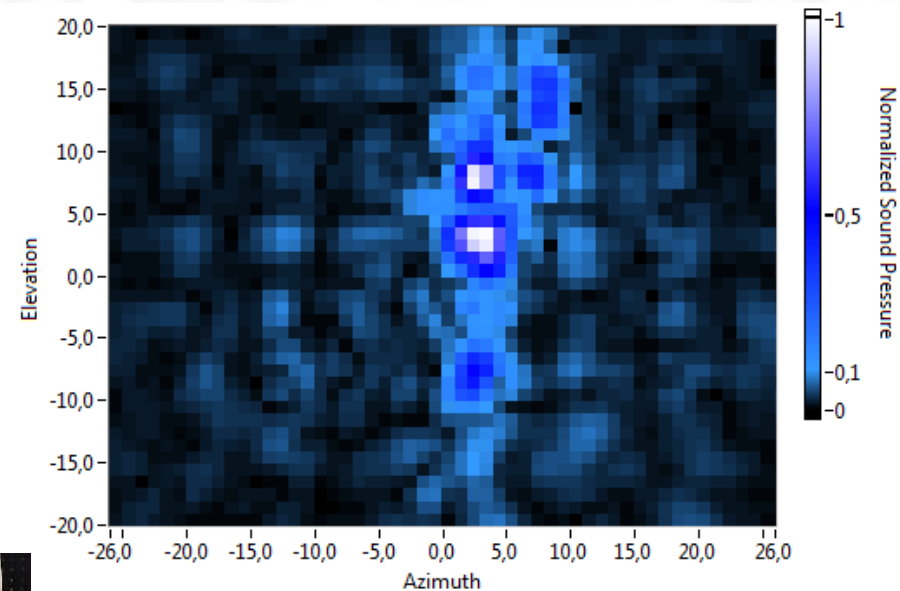
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- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range: 250 cm

Body parts identification

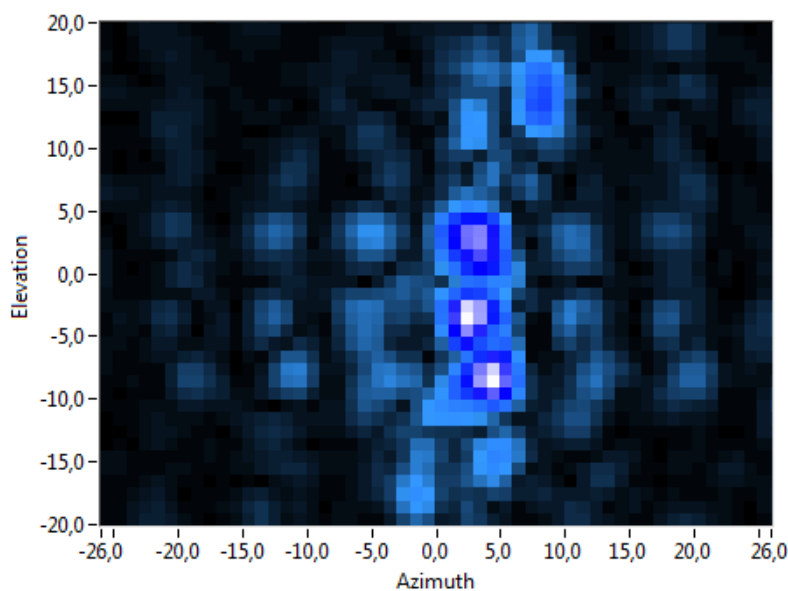


Results

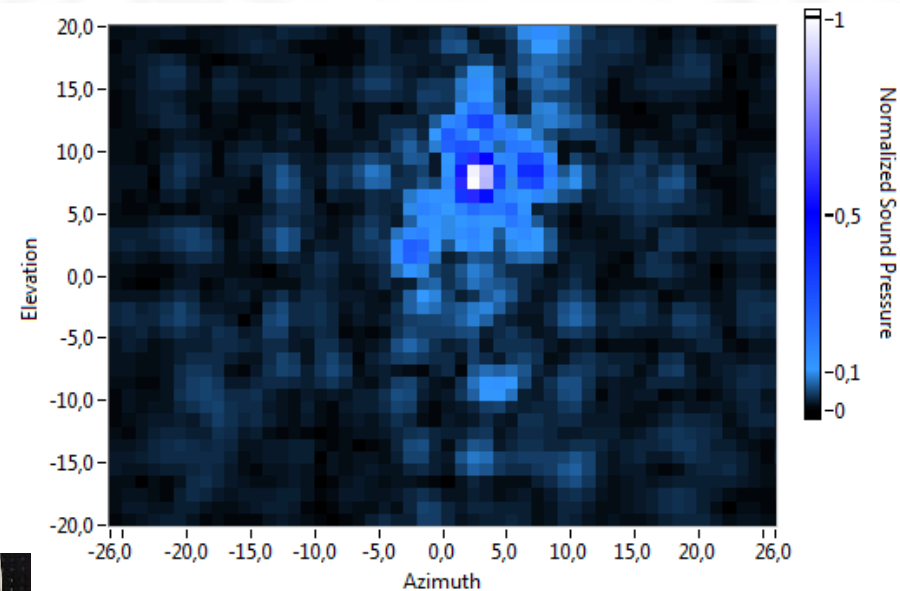
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- Mannequin **acoustic images**:

Range: 240 cm



Frequency: 1300 Hz



Frequency: 1500 Hz

↑ freq. → ↑ resolution

Range: 260 cm

Body parts identification



Conclusions

- Spatial resolution increment with virtual arrays
→ **High resolution acoustic images**



Use in identification biometric systems

- **Future work:**
 - **Acoustic images analysis** → extract representative parameters in the 4 dimensions (azimuth, elevation, frequency, range)
 - Obtaining **representative(s) dimension(s)** in identification tasks



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Thanks for your attention

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Alberto Izquierdo

Juan J. Villacorta

Luis Suárez

Marta Herráez

