



## DETECTABILITY OF ELECTRIC MOTORCYCLE

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- 3. Measures Processing
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# 1. INTRODUCTION

- OBJECTIVES AND BACKGROUND

# 1. INTRODUCTION



- OBJECTIVE:
  - ▣ Study the perception in electric vehicles from the road safety point of view. Focused on Motorcycles.
  - ▣ Evaluate the measurement protocols for establish the detectability of electric vehicles

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

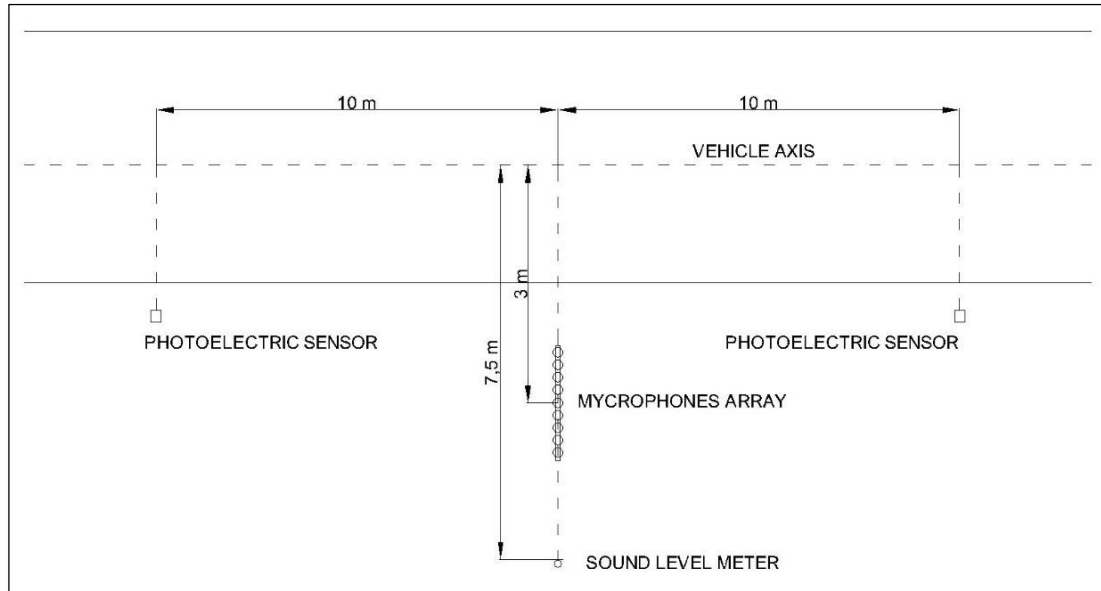
- MEASUREMENTS CONDUCTED
- CONFIGURATION
- SIGNAL ACQUISITION
- SOUND SAMPLES

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

- **MEASUREMENTS:** we have conducted a PASS-BY test obtaining the following measures:
  - Sound Pressure Level. ISO 362 (SPL)
  - Horizontal Sound Directivity with Lineal Array (HSD)
  - Audio Samples Acquisition. *Mototcycles* PASS-BY tests
  - Sound Pressure Level. Pedestrian Point of View

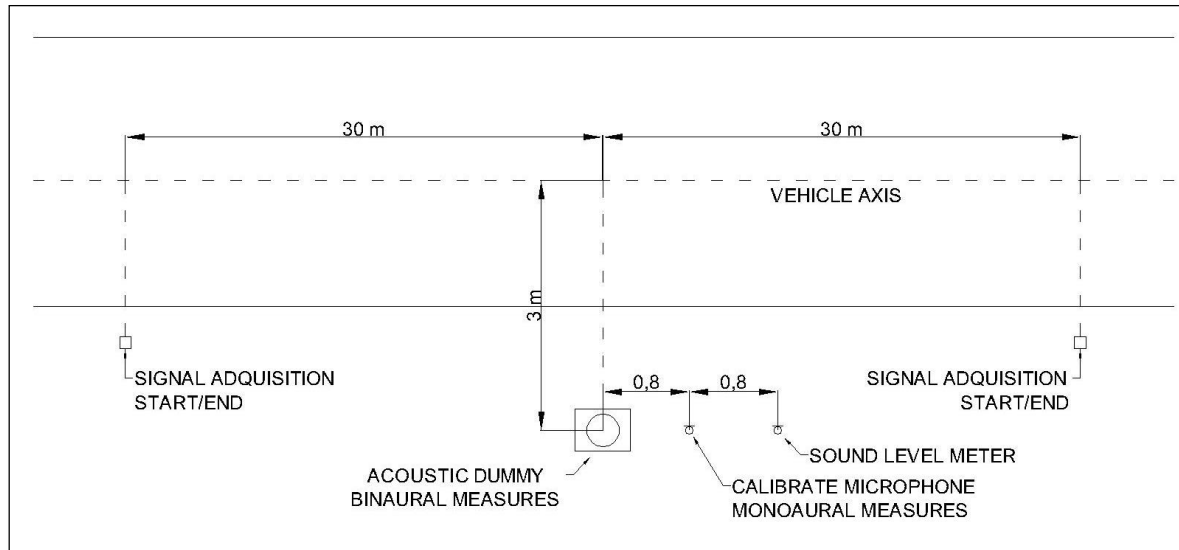
## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ CONFIGURATION: SPL & HSD



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ CONFIGURATION: Audio Samples





## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ CONFIGURATION:

- The measurements were performed at the University Miguel Hernández of Elche, on a road with a characterized asphalt G20 + S20



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ MATERIAL AND METHODS:

#### ▣ Binaural Measurements

- HEAD Acoustics HSM III.
- Sample Frequency: 44100 Hz.
- 16 bits with noise shaping algorithm.
- High-Pass Filter: 22 Hz, 5th order.
- Diffuse Field filter.



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ MATERIAL AND METHODS :

#### □ Monoaural Measurements

- 1/2" Prepolarized Microphone.  
PCB Piezotronics 377B02.
- Sample Frequency: 44100 Hz.
- 16 bits.
- High-Pass Filter: 20 Hz, 5th order.



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ MATERIAL AND METHODS :

#### □ Sound Card Acquisition

- TASCAM US-144MKii.
- S/PDIF. IEC60958 Standard\*

#### □ SPL Pedestrian Area

- Sound Level Meter B&K Type 2250.
- LAeq.



\*IEC60958 Standard. Recommended for consumer use.

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ MATERIAL AND METHODS :

#### □ SPL ISO 362

- Sound Level Meter B&K Type 2260.

#### □ HSD Microphone Array

- 9 Microphone B&K 1/4" 4935
- Acquisition System LMS Pimento 16 channels



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TESTED VEHICLES:

#### ▣ HONDA LEAD 110

- Monocilindre 4 times
- Equivalent Engine 108 cc
- Max. Power 6,6 kW
- Max. Par 9,3 Nm
- Weight 114 kg



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TESTED VEHICLES :

#### □ ETRICKS EVO 001

- DC Brushless
- Equivalent Engine 49 cc
- Max. Power 2,2 kW.
- Max. Par 55 Nm
- Weight 38 kg



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TESTED VEHICLES :

#### □ BRAMMO ENERGIA+

- AC Brushless
- Equivalent Engine 125 cc
- Max. Power 13 kW.
- Max. Par 40 Nm
- Weight 145 kg





## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TESTED VEHICLES :

#### □ SCUTUM S01

- DC Brushless
- Equivalent Engine 125 cc
- Max. Power 4 kW.
- Weight 90 kg



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TESTED VEHICLES :

#### □ ZUAP PRO

- Hybrid
- Equivalent Engine 125 cc
- Max. Power 13 kW.
- Weight 111 kg



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TEST CONDITIONS:

- Different Speeds: 10, 20, 30, 40 and 50 km/h\*
- 4 Iterations for each vehicle:
  - 2xPASS\_BY Left-Right
  - 2xPASS\_BY Right-Left
  
- TOTAL NUMBER OF SAMPLES: 112 audio files

*\*ZUAP Pro Motorcycle: maximum speed electric mode: 30 km/h*

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ TEST CONDITIONS:

▣ Start Time Test: 10:35 AM.

▣ End Time Test: 12:33 PM.

▣ Environmental Conditions:

■ Temperature: 23 – 27 °C

■ Humidity: 48 %

■ Wind Speed: 0'8 m/s (wind gusts 2'2 m/s after 11:54 AM.)

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ EXAMPLES:



Honda Lead



ETricks



Brammo



Scutum



Zuap Electric



Zuap Combustion

## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ EXAMPLES:



## 2. ACOUSTIC MEASUREMENT PROTOCOL. MOTORCYCLES

### □ EXPECTED RESULTS:

- Motorcycles Spectral Analysis. Critical Frequency Bands.
- Horizontal Directivity of the Vehicles
- SPL Comparison: IC vs EV/HEV
- Detectability of electric motorcycles in urban environments
- Psychoacoustic tests: annoyance

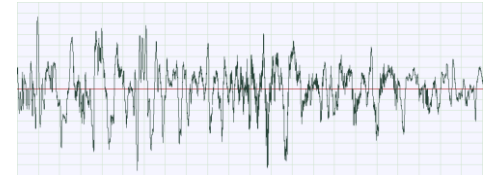
## 3. MEASURES PROCESSING

- SIGNAL PRE-PROCESSING
- SAMPLE SELECTION
- BACKGROUND NOISE ANALYSIS
- SIGNAL POST-PROCESSING

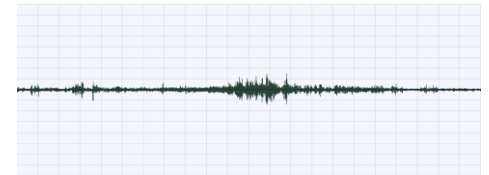


# 3. MEASURES PROCESSING

- Signal Pre-Processing. Global:
  - ▣ 80 Hz High-Pass Butterworth Filter, 5th order → wind noise removal
- Selection of Right Sound Samples
  - ▣ Samples removed:
    - Barking
    - Planes
    - Clipped by wind



Original Sample



80Hz Filtered Sample

# 3. MEASURES PROCESSING

## □ Background Noise



Birds



Barking



Planes



Ambulance

# 3. MEASURES PROCESSING

- Condition of Tested Vehicles. Mechanical Failures.
  - ▣ Untensioned Chain.
  - ▣ Friction.



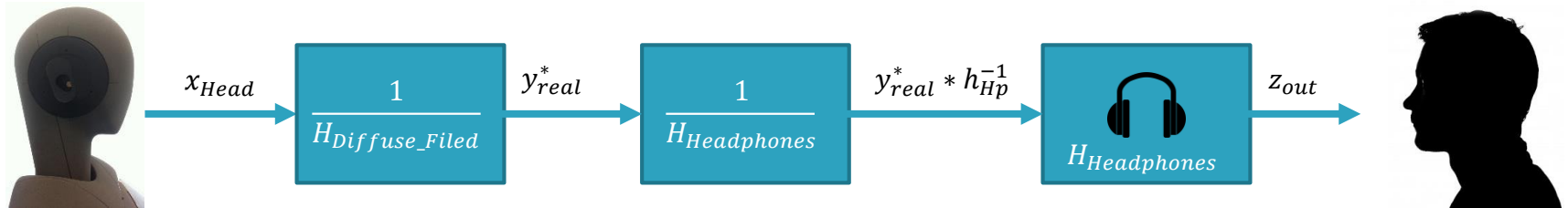
# 3. MEASURES PROCESSING

## □ Signal Post-Processing for Subjective Test:

- Headphones Equalization
- Recording Equalization (DF)



**Inverse filtering** by means System Impulse Response



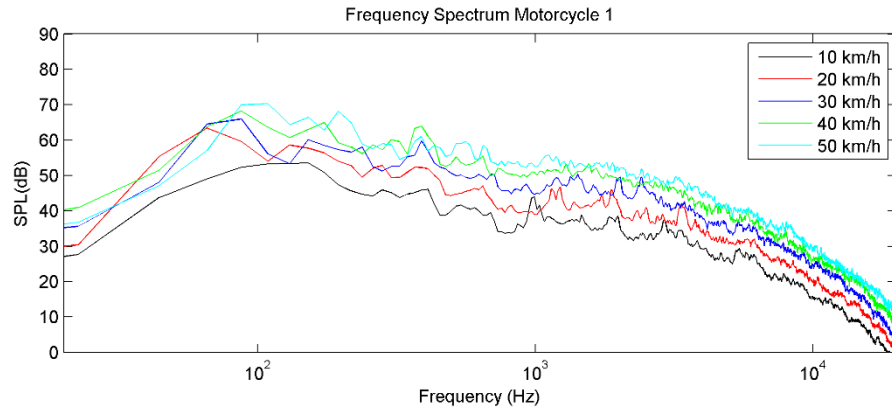
$$x_{Head} * h_{Diffuse\_field}^{-1} = y_{real}^* \quad \longrightarrow \quad y_{real}^* * h_{Headphones}^{-1} * h_{Headphones} = y_{real}^* * \delta = z_{out}$$

## 4. SPECTRUM ANALYSIS

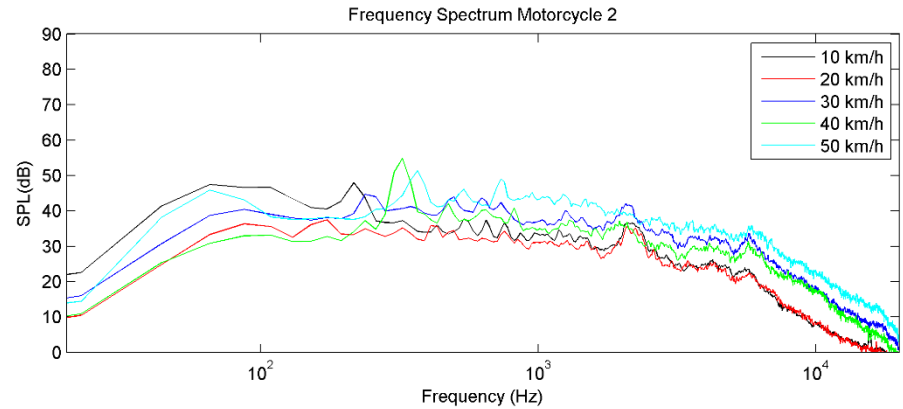
# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

### □ Spectrum Analysis



Honda Lead

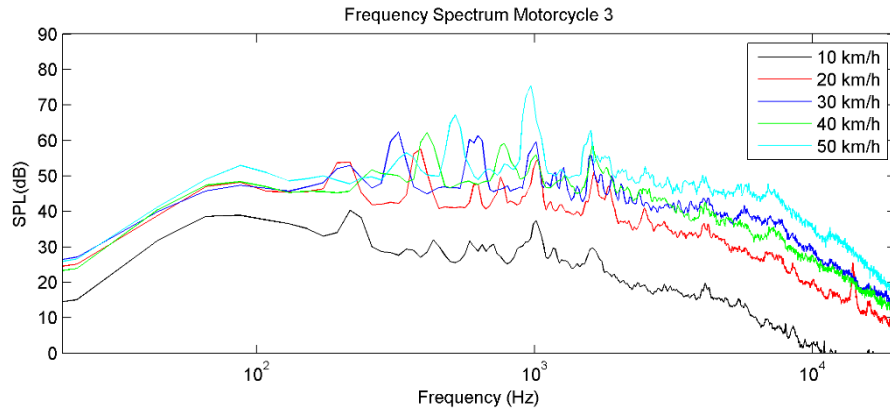


ETricks

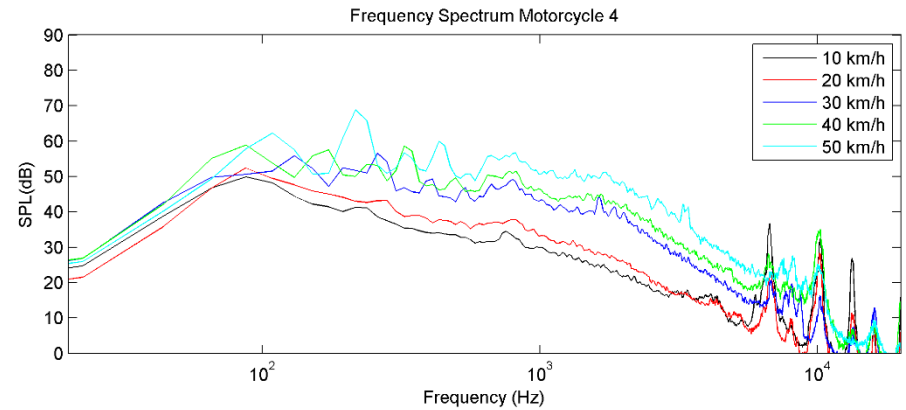
# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

### □ Spectrum Analysis



Brammo

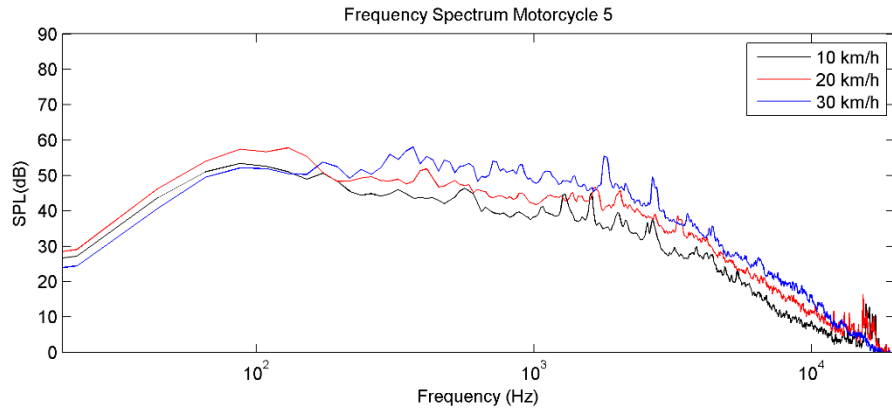


Scutum

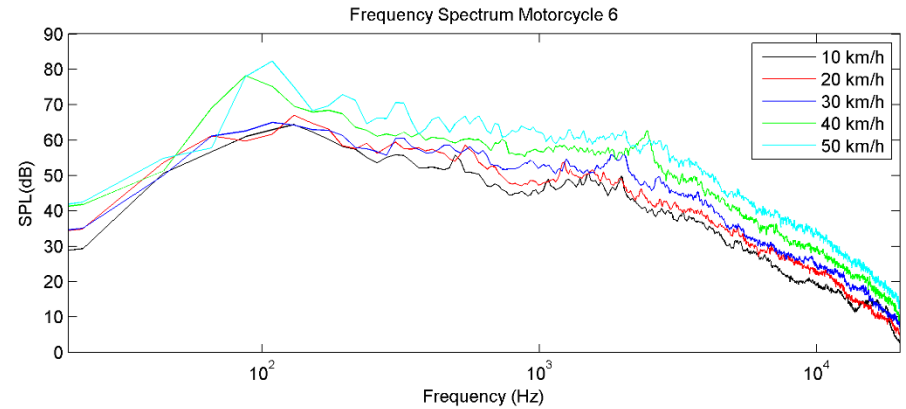
# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

### □ Spectrum Analysis



Zuap Electric



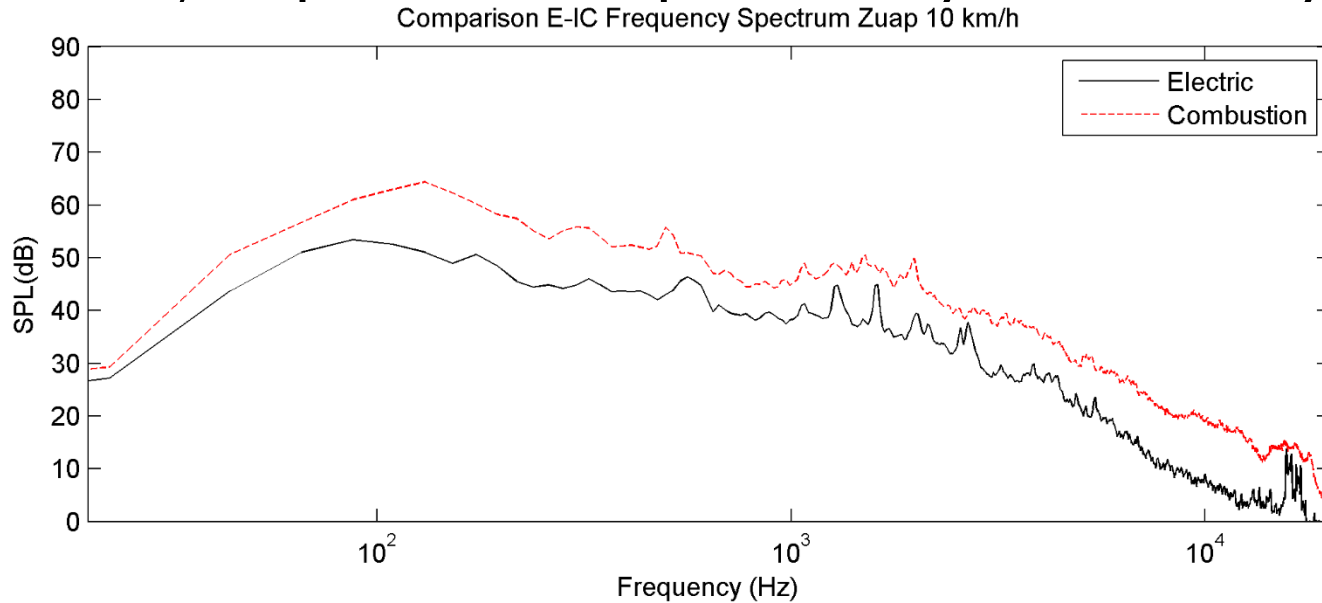
Zuap Combustion



# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

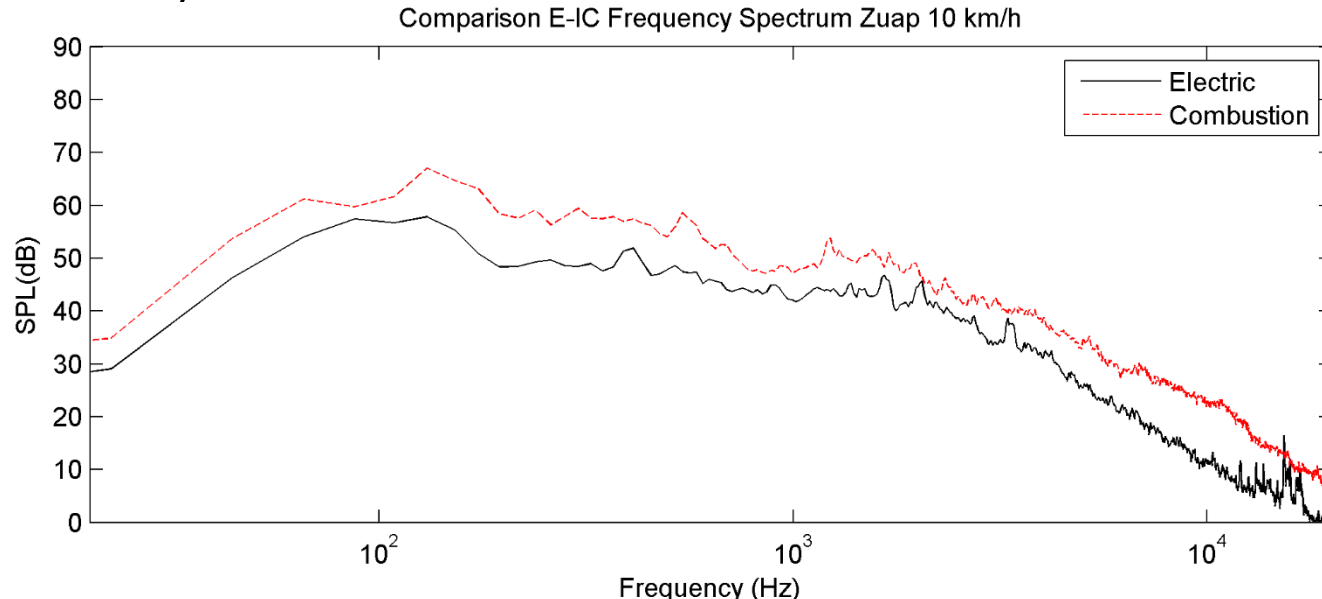
### ▣ 10 km/h Spectrum Comparison. Hybrid Motorcycle.



# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

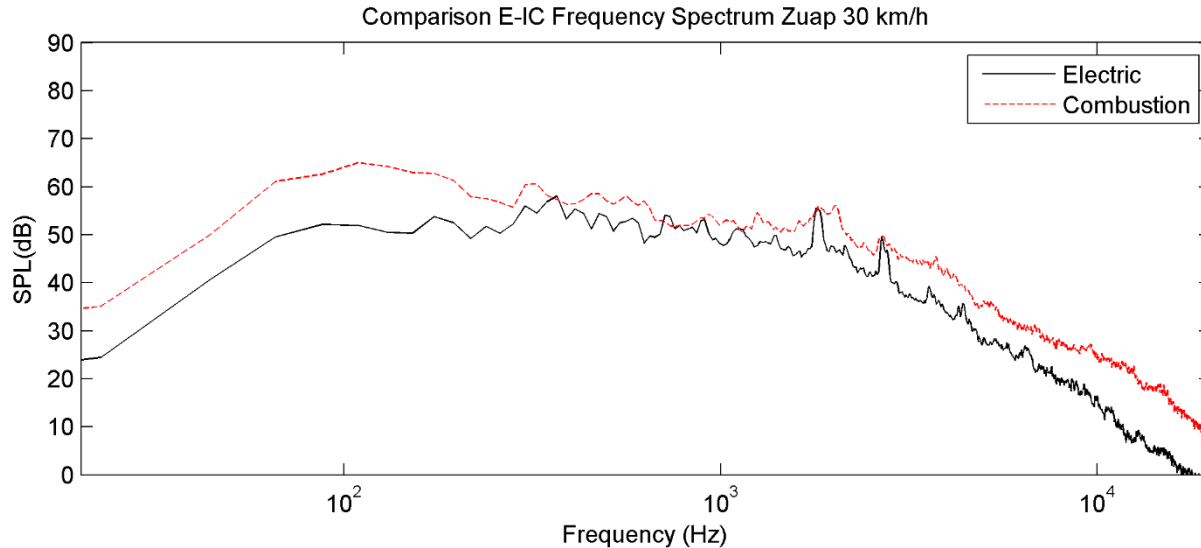
### ▣ 20 km/h Spectrum Comparison. Hybrid Motorcycle.



# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

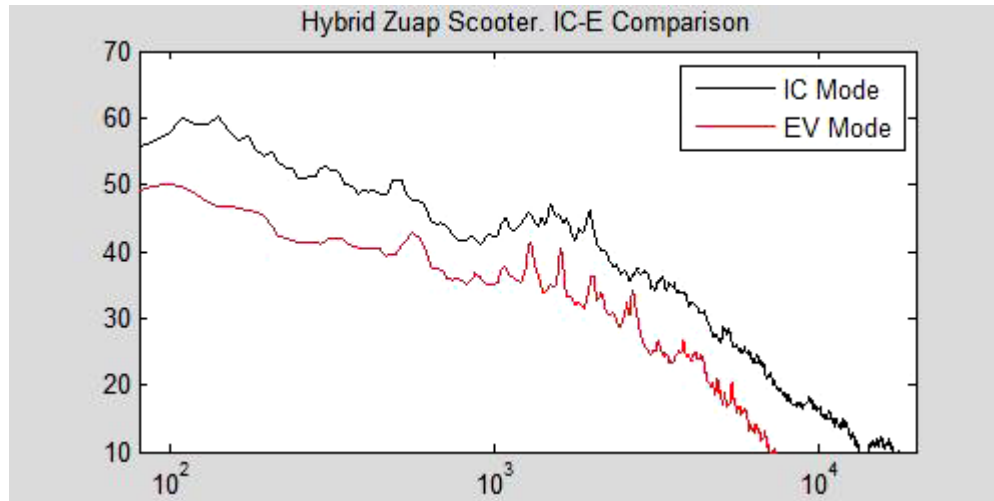
### ▣ 30 km/h Spectrum Comparison. Hybrid Motorcycle.



## 4. SPECTRUM ANALYSIS

### □ PRELIMINARY RESULTS:

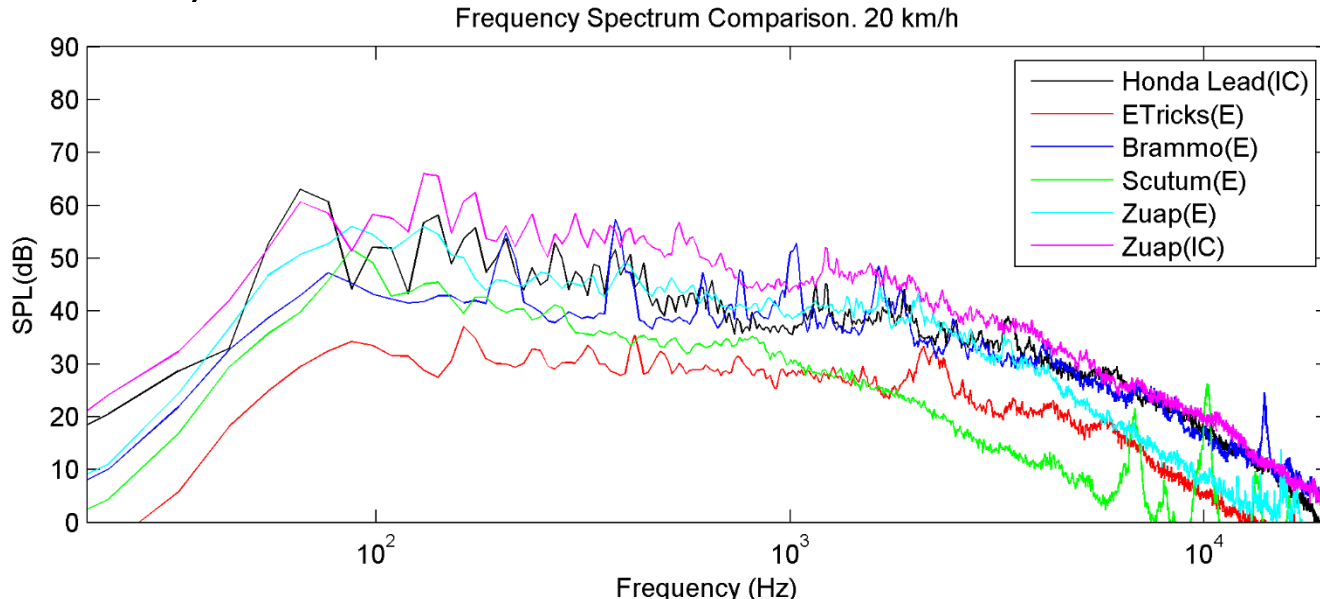
#### ▣ Spectrum Comparison. Hybrid Motorcycle.



# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

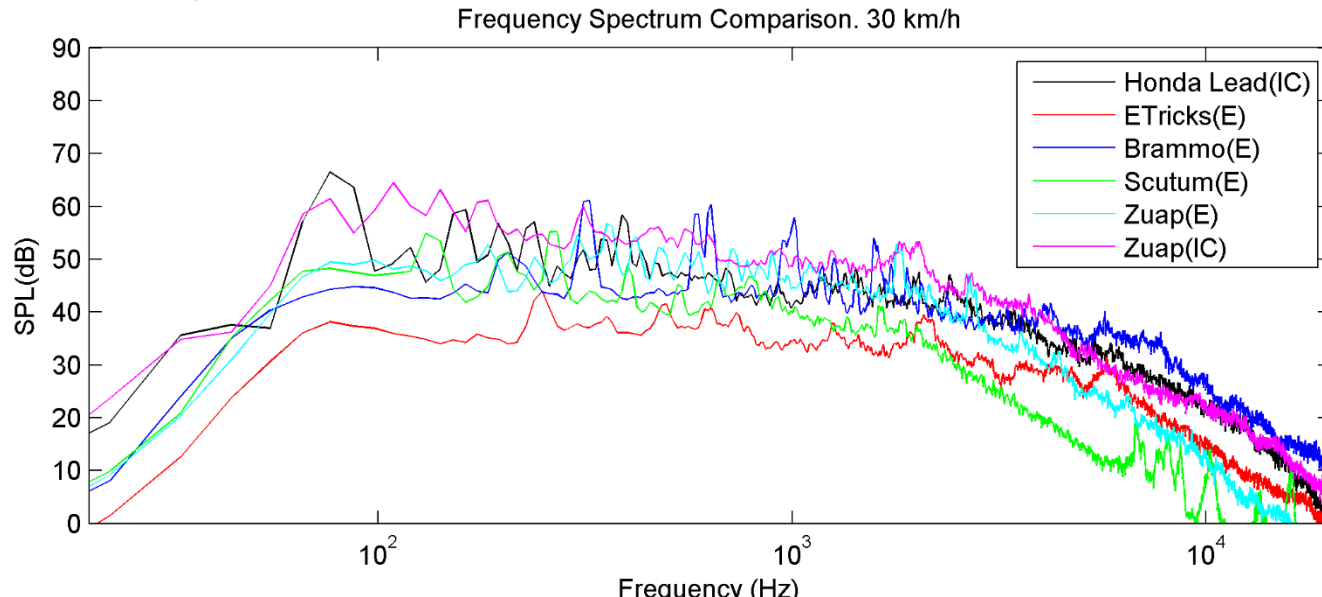
### ▣ 20 km/h Spectrum Comparison.



# 4. SPECTRUM ANALYSIS

## □ PRELIMINARY RESULTS:

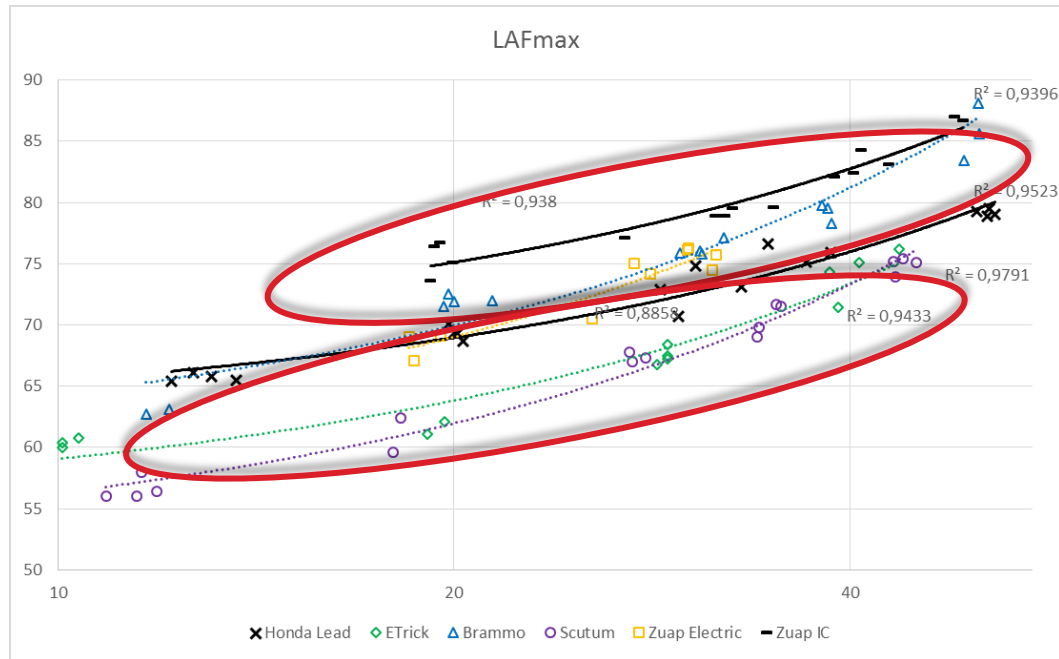
### ▣ 30 km/h Spectrum Comparison.



## 5. SPL ANALYSIS

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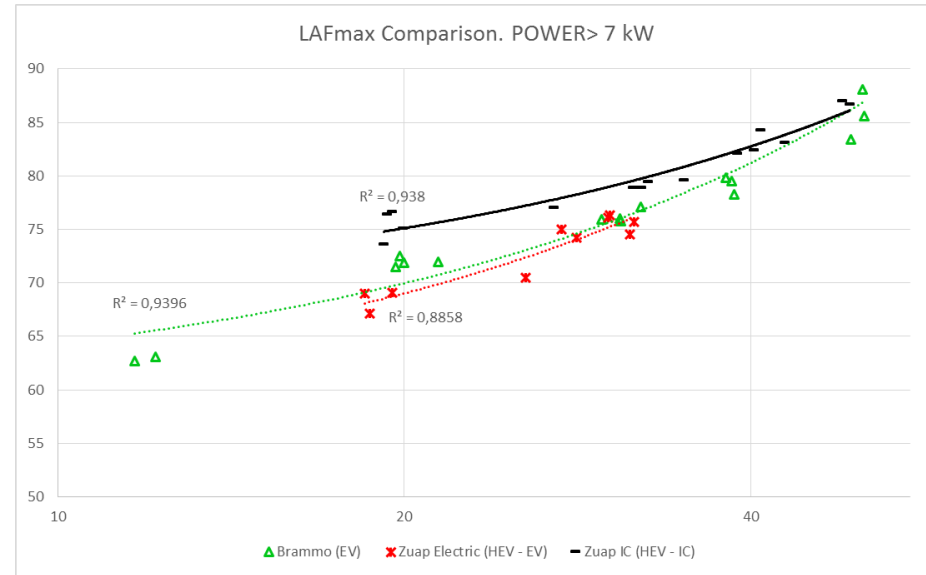
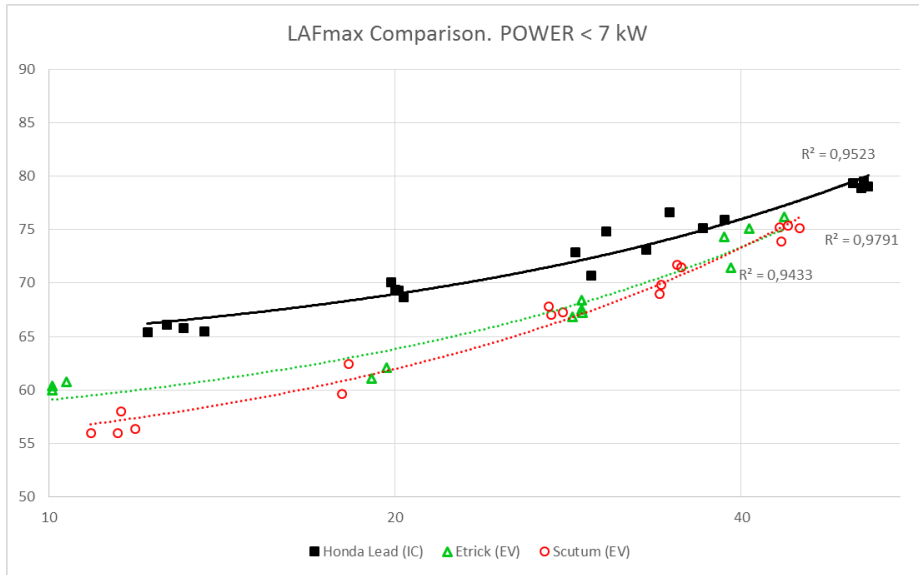
## □ IC/EV SPL Comparison (3m from the axis).






# 5. SPL ANALYSIS

## □ IC/EV SPL Comparison (3m from the axis).



## 6. DETECTABILITY TEST

## 6. DETECTABILITY TEST

- Detectability Test Setup:
  - A pedestrian standing on the sidewalk, at a distance of 3 meters from the centre of the traffic lane, prepared to cross the road.
  - The motorcycle approaches the listener individually, at a constant speed of **20 km/h**, covering a distance of  $\pm 30$  meters from the pedestrian.
  - The vehicles will be presented together with an urban environment background noise with a **SPL of 61,2 dB(A)**. 
  - The subject must indicate, by pressing a button, the moment he perceives the vehicle approach.

## 6. DETECTABILITY TEST

### □ DETECTABILITY:

#### ▣ Background Noise (SPL – Spectrum)

##### ■ Environments recorded

- Problem: pass-by vehicles included in the background noise can be confused with the pass-by vehicles included for the test

##### ■ White Noise Filtered Fitting it to Environmental Spectrum

- Problem: signal without dynamics. Unrealistic.

##### ■ Final option → static idle IC vehicles. 61'2 dB(A)

# 6. DETECTABILITY TEST

## □ DETECTABILITY:

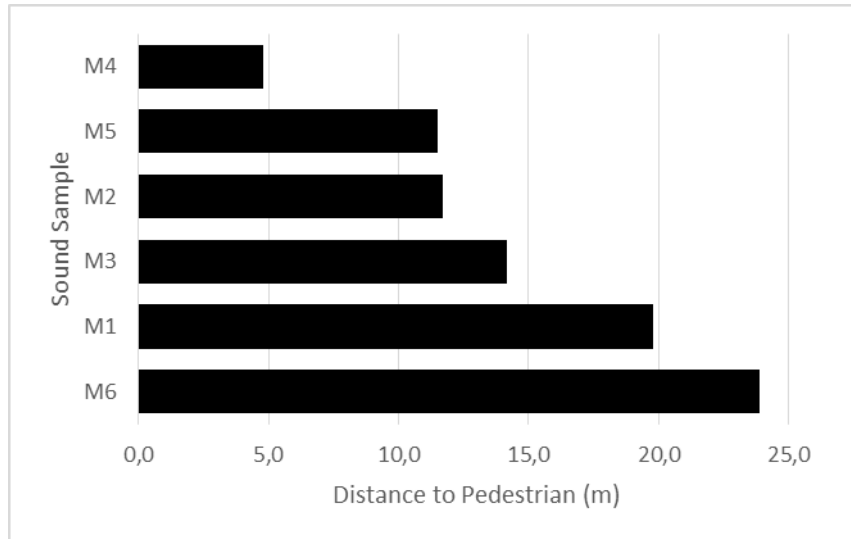
- Time between samples: 1 – 20 s. (randomly)
- How to validate the suitability of the candidate?
  - Audiometry
  - **Survey**

## 6. DETECTABILITY TEST

- Detectability Test. Preliminary Results:
  - ▣ 37 subjects (mean 25, median 20)
  - ▣ 48,65% female – 51,35% male
  - ▣ 5 motorcycles (1 IC, 3 Evs, 1 HEV)
  - ▣ 6 iterations (3xLR – 3xRL)

## 6. DETECTABILITY TEST

### □ Detectability Test. Preliminary Results:



- HEV IC mode – HEV E mode: aprox. difference 12'5 m.
- M4: distance to pedestrian  $< 5$  m.
- Minimum difference in reaction time between ICs and EVs  $\rightarrow 1$  s. (5,5 m)

Kruskal-Wallis Test:  $H(222) = 164,43$ .  $P < 0,05$ . Significant difference between groups



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