Measurement of noise from electrical vehicles and internal combustion engine vehicles under urban driving conditions

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Summary

As part of the electormobility+ project COMPETT controlled pass by (CPB) noise measurement where carried out in 2014. This was done in order to investigate differences in pass by noise from electrical vehicles (EV) and internal combustion engine vehicles (ICE) under urban driving conditions. The measurements where done on two EV's and two similar ICE's. The measurements were done with an electrical and an ordinary Citroën Berlingo and a Nissan Leaf and a VW Golf Variant. The Citroën's and the Nissan was lent by the dealer while the VW is one of the cars in the fleet of the Danish Road Directorate. The tires on the electrical Berlingo were Michelin Agiglis the other cars were supplied with Michelin Energy saver. The urban driving conditions investigated was steady driving at 10, 20, 30, 40, 50 and 60 km/h, deceleration by engine breaking from 60, 50, 40, 30 and 20 km/h and acceleration at various degrees. These measurements should make it possible to investigate the noise levels from EV's and ICE's at diving conditions such as: coming up to and going away from a crossing, diving along at steady state in parking lots, on open streets and in streets with low speed restriction etc. The study shows that at low speeds in decelerating by engine breaking and steady driving the Ev's emits about 5 dB less noise than ICE's, but at speeds above 30 km/h the noise levels from EV's and similar ICE's are similar as well.

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1. Introduction

Electric power units in vehicles are often considered almost completely silent. The largest source of noise in urban areas in Europe is the road transport system. There is no easy solution to this noise issues. The solution will consist of a combination many measures, one of these could be the introduction of electrified vehicles. The electromobility+ project COMPETT will investigate the possibilities to reduce traffic noise in urban areas by electrified vehicles.

The first deliverable on noise in the electromobility+ project COMPETT was a State of the art report on noise and electrical vehicles [1]. This report was presented in 2013 on Internoise in Innsbruck. The conclusions of the report recommended that more knowledge about the tires used on electric cars were needed. And that measurement of different driving situations such as acceleration and braking are needed.

The measurements which are being described and analysed in this paper where done in order to investigate differences in noise emission in Urban driving situations between EV's and ICE's.

2. Measurements

Urban driving situations with uneven driving pattern are supposed to cause higher noise level emitted from the engine of the vehicle.

Controlled pass by (CPB) measurement were carried out in according to the ISO standard method described in [3]. By this it is possible to measure noise emission from specific vehicles under given driving conditions.

1.1. Vehicles

Four cars where used in the measurements, two Citroën Berlingo's an ICE and an EV, a Nissan Leaf and a VW Golf Variant ICE, se figure 1. The Berlingo's and the Nissan Leaf were kindly lent to the Danish Road Directorate to conduct these measurements from the care suppliers. The VW Golf Variant is one of the cares in the fleet of the Danish Road Directorate. The cares were chosen to be similar in pairs to justify the comparison of the noise emissions.

Figur 1: The cars included in the measurements from the left to right: Citroën Berlingo EV, Citroën Berlingo ICE, Nissan Leaf and VW Golf Variant.

The cares were supplied with different tire types, see table I. The Berlingo EV were supplied with Michelin Agigilis The other cars where supplied with Michelin Energy Saver of different dimensions. The tires of the Golf and the Leaf have the same dimensions. In table I the noise label of the tires are listed. The Michelin Agiglis tires are labeled with a higher noise level than the Energy saver. EV's are normally supplied with tires with low rolling resistance, such as the Energy Saver.

1.2. Driving conditions

Three different driving conditions were measured to investigate the typical uneven driving pattern from urban driving situations. Steady speed at 10, 20, 30, 40, 50 and 60 km/h, decelerating and acceleration.

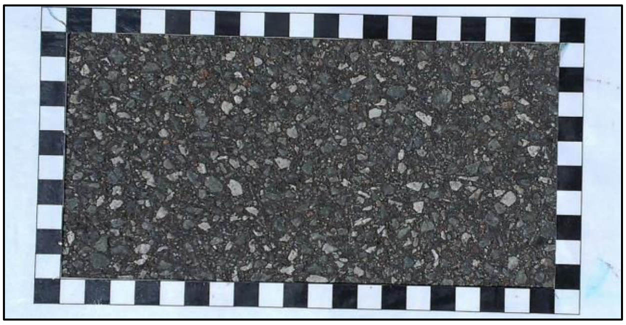

Figure 2: The pavement on the test sight

Steady driving at low speeds would simulate driving in carparks and low speed roads. Deceleration and acceleration would simulate the driving situations at crossings.

1.3. Test site

The noise emitted from cars driving at speeds under 30 km/h is dominated by the propulsion noise. It is the normal opinion that EV's are very silent at low speeds. Thus the test site had to be silent, and without disturbing traffic. The surface should have no signs of ware, which could be suspected to pollute the measurements.
A large carpark in an industrial area was chosen. The lane connecting the different sections of the carpark had been repaved within the last 2 or 3 years and had no sign of ware, see figure 2. It is assumed that the pavement is soft asphalt (dense graded asphalt concrete with soft binder).
The traffic at the carpark was limited to one or two cars throughout the whole measurement.
It was possible to find a microphone position fulfilling the requirements of the ISO standard [3]. The microphone was placed 7.5 m from the center of the driving lane and 1.2 m above terrain, see figure 3. Traffic cones were placed before and after the measuring zone to guide the driver to drive in right lane.
The cones were also used to control the driving pattern. In steady speed diving situations, the steady speed should be achieved at the traffic cone before the measuring zone and held until passing

Table I. Tyre model, size and labeled noise level

Citroën Berlingo EV	*Citroën Berlingo ICE*	*Nissan Leaf EV*	*VW Golf Variant ICE*
Michelin Agiglis 51 195/70 R15C 71 dB	Michelin Energy Saver 195/65 R15 G1 69 dB	Michelin Energy Saver 205/55 R16 70 dB	Michelin Energy Saver 205/55 R16 70 dB

the traffic cones after the measuring zone.

In the measurement of noise emission from decelerating cars, the car should drive at steady speed until it reached the traffic cones entering the measuring zone, where the driver should release the foot from the gas pedal. The car should then decelerate using engine beak through the measuring zone

Figure 3: The test site seen from behind the microphone while the Nissan Leaf is passing by. To the right one of the traffic cones before the measuring zone is seen.

When measuring the noise emission from accelerating cars, the car should drive up the first traffic cones with steady speed accelerating through the measuring zone trying to reach a given speed at the last cones.

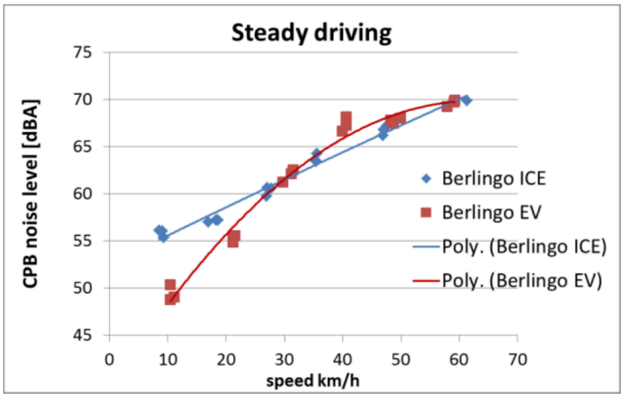

Figure 4: Results of the steady speed CPB measurement of the Citroën Berlingo's.

2. Results

The measurements were carried out Saturday, the 22th of June, 2014 between 10:30 am and 12:45 pm and the temperature was 16.6 °C. The results are normalized to 20 ° C using a correction factor of -0.05 dB per °C.

2.1. Steady speed

Figure 4 shows the results and polynomial trend lines of the measurements for the Berlingo's driving in the measuring zone a various steady speeds. The EV emits 5 dB less noise than the ICE at 10 km/h, at 30 km/h and 60 km/h they are equally noisy. Between 30 km/h and 60 km/h the ICE emits less noise than the EV with a maximum difference of about 2 dB.

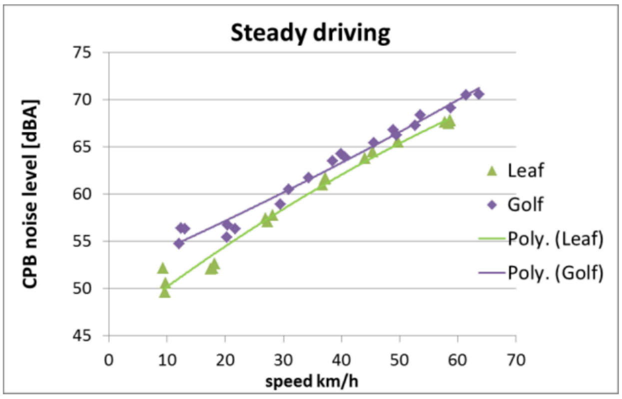

Figure 5: Results of the steady speed CPB measurement of the Nissan Leaf and the VW Golf Variant

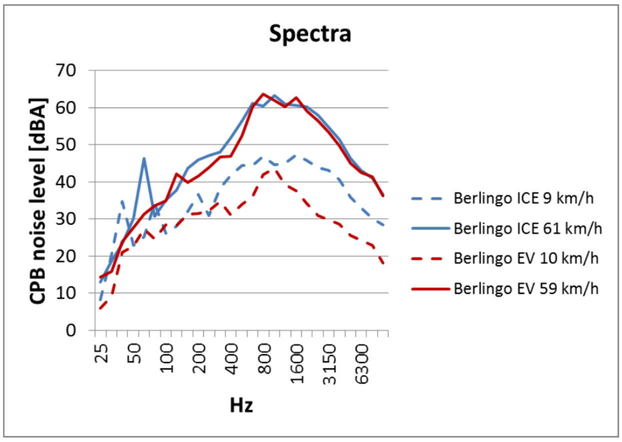

Figure 6: Spectra from CPB measurements of the Citroën Berlingo's driving at steady speed.

The results and the polynominal trend lines of the Nissan Leaf and the VW Golf are shown in figure 5. At all speeds the Leaf emits less noise than the Golf. At about 10 km/h the Leaf emits about 4 dB less noise than the Golf but the difference is only 1.5 dB at about 60 km/h.

Figure 6 and 7 shows A-weighted 1/3 octave band spectra for noise levels measured at low and high speed for each car.

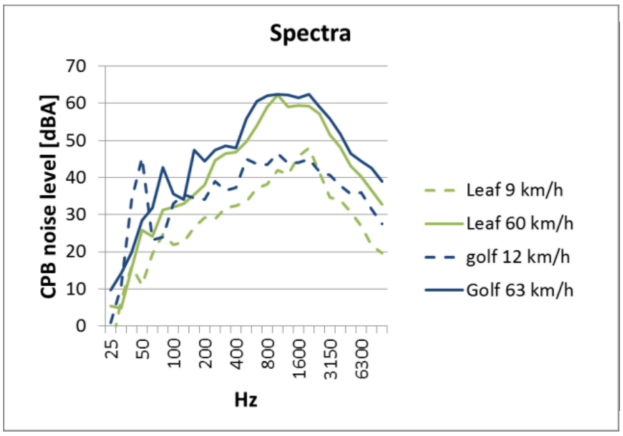

Figure 7: Spectra from CPB measurements of the Nissan Leaf and VW Golf Variant driving at steady speed.

Both EV has a narrow peak in the spectra at low speeds. The Berlingo has its peak at 1 kHz and the Leaf has its peak at 2 kHz.

2.2. Engine brake

The results and the polynomial trend lines of the measurement of deceleration by engine braking are shown in figure 8 and 9.
For the Berlingo's the EV is emitting about 4 dB less noise than the ICE at about 15 km/h. But at 30 km/h and higher speeds the noise levels of the two Berlingo's are similar.

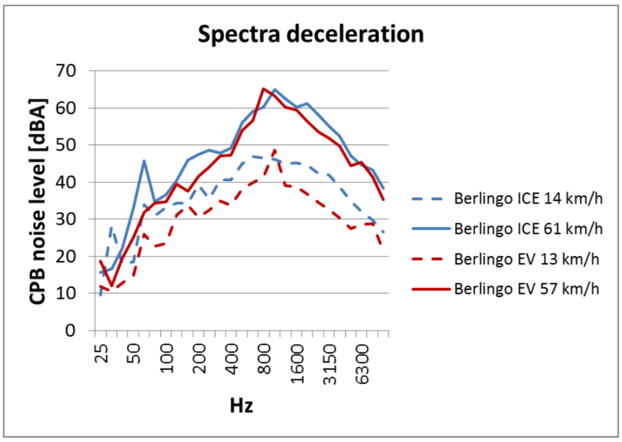

Figure 8: Results of the deceleration CPB measurement of the Berlingo's.

The Leaf is less noisy than the Golf at all the measured speeds. At about 20 km/h it is 2 dB and at about 60 km/h it is 1 dB less noisy.

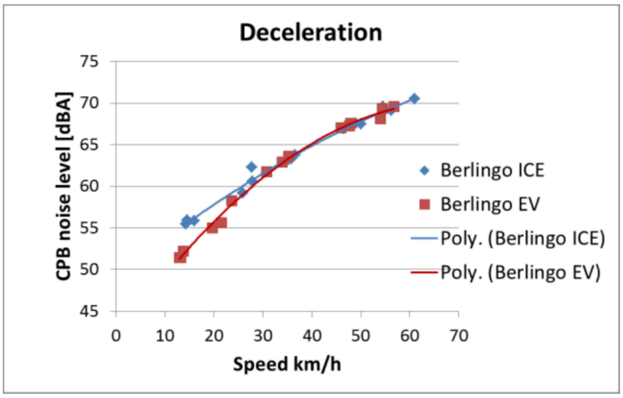

Figure 9: Results of the deceleration CPB measurements of the Nissan Leaf and the VW Golf Variant.

Figure 10 and 11 shows A-weighted 1/3 octave band spectra for noise levels measured during deceleration by engine brake at low and high speed for each car.

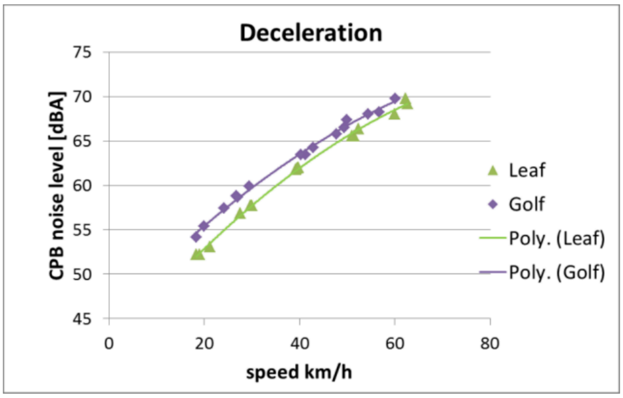

Figure 10: Spectra from CPB measurements of the decelerating Berlingo's.

The Berlingo EV has a narrow peak in the spectra at 1 kHz at low speed and at 800 Hz at high speed. The Berlingo ICE has a slight peak at 1 kHz at high speed and no peak at low speed.
The spectra in figure XX for both the Golf and the Leaf shows a slight peak for both at 1 kHz at 18 km/h and no significant peak at high speed.

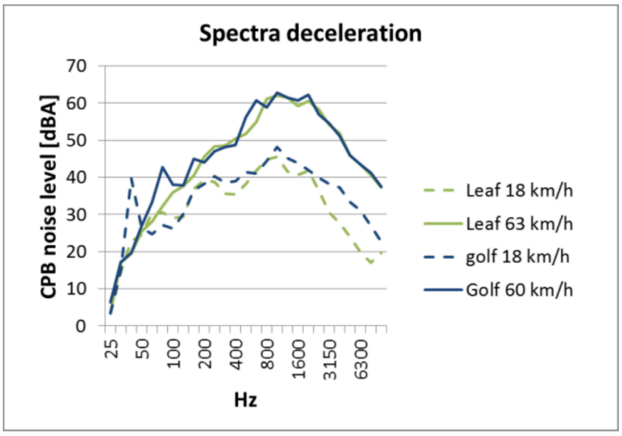

Figure 11: Spectra from CPB measurements of the decelerating Nissan Leaf and VW Golf Variant.

3. Discussion

In the preceding sections the results of CPB measurements made to investigate the differences in noise emission from EV's and ICE's of similar vehicles in different driving conditions which would occur in urban areas.

3.1. The two Berlingo's

Noise levels from two Berlingo's, an EV and an ICE, were measured in different driving conditions. The EV was mounted with tires labeled noisier than the tires mounted on the ICE. This is probably why the EV is emitting more noise than the ICE at steady speed at speeds between 30 and 60 km/h. When decelerating at various speeds the two Berlingo's emits similar noise levels at speeds above 30 km/h.

When comparing the trend lines of the Berlingo's in the two driving situations the ICE has the same level at 10 km/h for both situations, while the EV has a slightly (about 1 dB) higher level when decelerating. Between 30 and 60 km/h the EV emits the same levels for both driving situations, while the ICE emits about 1.5 dB higher noise level. This might be explained by the suspicion of noisier tires on the EV. The tire road noise will be dominant at a lower speed level when the tires are noisier and the engine is less noisy. The electric engine will be emitting more noise when decelerating than in steady speed driving situations. This will explain the slightly higher noise level at low speeds in the deceleration measurements. The less noisy tires on the ICE will mean that the tire/road noise will be become dominant at a higher than if noisy tires were mounted on the car.

The spectra in figure 6 and 7 shows that both in steady speed and deceleration driving situations the EV has a narrow peak at 1 kHz these peaks are heard when the car is passing by, and can be described as annoying especially in the case of deceleration by engine brake.

3.2. The Leaf and Golf

The noise levels form a Nissan Leaf and a VW Golf Variant with similar tires were measured in different driving conditions. The Leaf was emitting less noise for all speeds between 10 and 60 km/h under both driving condition, but the difference were getting smaller as the velocity went up. This could be explained by the fact that the tire/road noise is becoming more dominant the higher the speed. This can also be seen in the spectra, where there is a big difference between the Leaf and The Golf at low speed, while at higher speeds the spectra is getting more similar because of the dominance of the tire/road noise.

4. Conclusions

EV's are 4-5 dB less noisy than similar ICE at low speed when driving at steady speed. But at about 30 km/h the difference in emitted noise is not significant. For speeds higher than 30 km/h the tire/road noise gets dominant and from there on the choice of tire is more essential to noise reduction.

When decelerating by engine breaking the EV's are 2-4 dB less noisy than ICE's at low speed. At higher speed the difference decrease as the tire/road noise is getting dominant.

It can be concluded that EV's will reduce the traffic noise in carparks and on streets with low speed restriction where the velocity of the vehicle will be under 30 km/h. In urban areas where the speed it often above 30 km/h the introduction of EV's will not have a great influence on the traffic noise.

If speed restrictions under 30 km/h are introduced to lower the noise in recreational areas, then the introduction of EV's would make these areas even less noisy. But for some EV types there are narrow peaks in the spectra at low speed which are possible to hear, and could be described as annoying.

Acknowledgment

The Berlingo's were kindly lent to the Danish road directorate by Citroën Denmark A/S. Autonorden A/S kindly lent the Nissan Leaf to the Danish road directorate. The municipality of Copenhagen supplied the Danish road directorate with the contacts.

References

[1]http://compett.org/documents/wp_3_report_noise_from_electric_vehicles_a_literature_survey.pdf

[2] Acoustics – Measurement of the influence of road surface on traffic noise, ISO 111819-1:1997(E)