Vehicle Audio Systems; Exterior Noise Levels

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Introduction

In-vehicle audio entertainment systems are fitted to most new vehicles and are considered one of the most important car accessories. Primarily, car audio sound systems are designed to fill the enclosed vehicle cabin space with sound at moderate sound pressure levels sufficient to allow for listening pleasure and to reduce the intrusion of road and vehicle-related sounds at open road cruising speeds. Over recent times a trend has developed whereby high power sound systems are being installed in some vehicles by audio enthusiasts which provide high interior sound pressure levels, with ensuing effects on exterior vehicle noise levels.

There is now wide acceptance of car audio as a legitimate hobby pursuit in most western nations of the world, with regular competitions being held in the main urban centres where car audio systems are judged in competitions. One of the common categories for competition is the "sound off", ie. a competition to record the highest interior sound pressure level (L_{max}) at a microphone position representative of the driver's ear.

Whereas modern high-powered car audio systems are designed to provide a certain interior acoustic climate, the subject of this investigation has been the influence of such systems on exterior vehicle noise levels. Sound emitted into the cabin interior has the ability to penetrate the car body and be received at appreciable levels at positions outside the vehicle. The levels at which sounds are emitted from the vehicle are related to the type of vehicle (areas of glazing, sealing of doors and windows, panel size and construction, internal acoustic absorption, and the general type of car body construction [1]) and the system amplification, size, number and positions of speakers, the type of sound being reproduced and operating sound levels of the car audio system.

This paper has been based on measurements from a range of medium sized car audio systems (50 to 150 watts rms per channel), which are relatively common in car audio terms. The measurements were performed during both stationary tests and during vehicle pass-bys. Stationary measurements were performed in order to characterise the typical exterior sound from vehicles operating moderately powered audio systems. Pass-by sound levels (at three different speeds, and with windows open and closed) were used to quantify the sound levels received at typical roadside positions.

The results indicate that at reported typical interior sound levels, the exterior levels are significant and have a marked effect on pass-by sound levels (at speeds of up to 50 km/hr). Although each pass-by has a clearly distinguishing effect on roadside sound levels, the contribution to overall traffic noise levels may in fact be quite small due to the minor proportion of vehicles fitted with such systems.

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Overview of In-Vehicle Audio Entertainment Systems

Modern car audio systems generally fall into two categories; factory fitted low/moderate power systems, and specially installed high power after market units.

Factory Fitted "Low/ Moderate" Power Systems

Factory fitted units (comprising simply of a compact disc/radio or cassette deck/radio head unit attached to a simple speaker array) are generally low power systems that have been tested in three late model vehicles at maximum sound pressure levels (at a position representative driver's ear) of

between $Leq_{A,90\ sec}$ 82 and 93 dBA. As indicated by test results from high powered systems below, such systems have internal sound levels similar to the external sound levels measured from high power systems. External sound levels (at 7.5 metres) were measured in the range of 50 to 62 dBA. Factory fitted units in new cars therefore do not appear to appreciably affect exterior sound levels.

High Performance Systems

High power units fitted after-market vary considerable in their size and configuration. Systems varying from 50 to 1,000 watts or greater are installed in some cars. Multiple amplifier systems powering various speaker configurations are a common feature. Typically high power systems employ sub-woofer speakers (300 mm diameter) which are housed in specially built enclosures. Such systems have the capability to produce internal sound levels in excess of 130 dBA, with many enthusiasts reporting average listening levels during normal driving of between 90 and 100 dBA.

It is the aim of this paper to describe the effects of such car audio systems on sound levels received at typical roadside positions during normal urban driving conditions ie. at vehicle speeds of between 35, 50 and 75 km/hr.

Method of Investigation

The objective of the measurement program was to firstly characterise

Car No.	Car Type	Rated sound power	Number of	No. Speakers	No. Speakers
14	Mazda 323	95	3	2 + sub	2
15	Ford Escort	120	2	2+ 2 subs	4
16	Mazda 323	80	3	2 + sub	2
17	Toyota Starlet	140	4	4 + 2 subs	2 + "Bazooka"
18	Ford Cortina	80	2	2	4
19	Toyota Carona	50	2	2	2
20	Ford Falcon	120	3	4 + 2 subs	4
21	Honda Civic	100	3	2 + sub	4

Table 1 Summary descriptions of audio systems involved with the measurement programme.

the external sound levels from typical high powered audio systems during stationary tests, followed by testing during vehicle pass-bys. The co-operation of entrants in a local car audio competition was obtained to provide the test vehicles. Eight vehicles were offered for testing. The vehicles were typical small 4 door family cars (eg. Mazda 323, Honda Civic). The vehicles were fitted with a variety of audio systems as described in Table 1.

A key aspect of the vehicles used in the measurement programme was that, apart from their audio systems, the cars were reasonably similar in all other respects to typical model types (in particular, tyres were no wider than 215mm, and the exhaust system was in good repair and had not been modified). A generalised site layout for both the stationary and pass-by tests is shown in Figure 1.

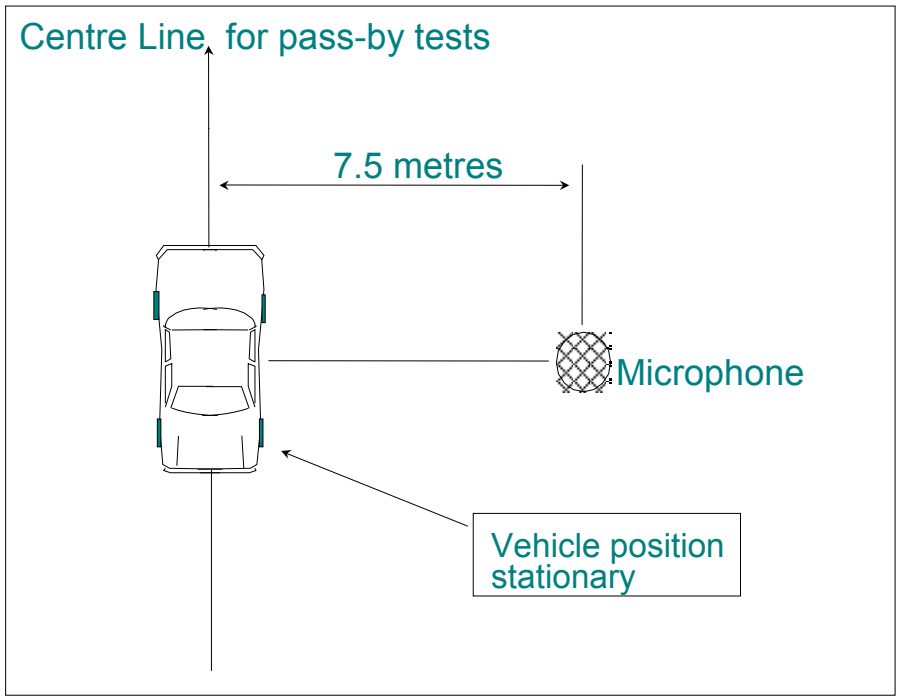

Figure 1 Generalised test layout.

Stationary Tests

The method of measurement was to undertake external sound pressure level measurements at 7.5 metres from the centre-line of the vehicle) with a stationary vehicle (engine not running). The source level within the vehicle was standardised at $Leq_{A,120\ sec}$ 100 dBA (at the position of the driver's ear), with the same 2 minute music track being played in all cases. Vehicle doors and windows remained shut throughout the test.

The results are presented in Table 2 and Figure 2.

The results indicate that the frequency content of the external measured sound pressure levels is dominated by low frequency sounds. There are obvious differences between vehicles and this is attribute to variations in vehicle type and sound system installed. In most cases panel vibrations caused by the internal sound level were visible. Internal sounds also caused vibrations of accessory items attached to the body of the car (which produced a small amount of noticeable sound). Two noticeable items that were vibrating were number plates and wing mirrors.

Pass-By Measurements

Pass-by measurements aimed to reproduce the influence of car audio sound on exterior vehicle sound levels (L_{max}, "fast" response) in typical constant speed urban driving conditions at speeds <75 km/hr. The method involved a similar test arrangement to the stationary tests (interior sound levels at 100 dBA, all vehicles using same music track, site layout as per Figure 1). The road surface was a

	Octave Band (Hz)									Overall	
test	31.5	63	125	250	500	1k	2k	4k	8k	A	Lp
14	82.5	94	78.2	72.1	68.1	61.3	55.1	44.8	38.7	79.4	94.4
15	88.2	91.2	88.6	76.1	66.2	58.5	49.6	46.3	43.2	82.0	94.4
16	81.6	87	81.2	77.9	67.2	56.7	45.8	42	34.1	78.2	89.3
17	76.9	86	84.2	71.2	67.9	54.2	54.2	37.2	34.7	77.7	88.6
18	81.2	88.7	70.7	65	57.8	62.4	61.4	54	42.3	74.2	89.5
19	75.5	88.9	73.8	73.5	69.9	64.9	61.1	54.3	49.4	76.9	89.4
20	80.8	97.5	83.6	66	65.9	61.7	58.4	54.7	44.4	82.5	97.8
21	75.6	93.1	76.1	70.9	64.7	55.1	50	44.5	43.4	78.1	93.3

Table 2 Exterior Sound Level Measurement Results for 8 vehicles, at 7.5 metres.

moderately worn chip seal surface (chipping size 12 mm). Hard ground surfaces were present between the vehicle path and the measurement point. Vehicles were operated at constant speed (35, 50, and 75 km/hr) past the measurement point (at 7.5 metres from the centre-line of the vehicle) with and without the audio system operating. All cars used 2nd gear for the 35 km/hr test, and top gear for the 50 and 75 km/hr test. The results are shown in Figure 3 for the eight test cars.

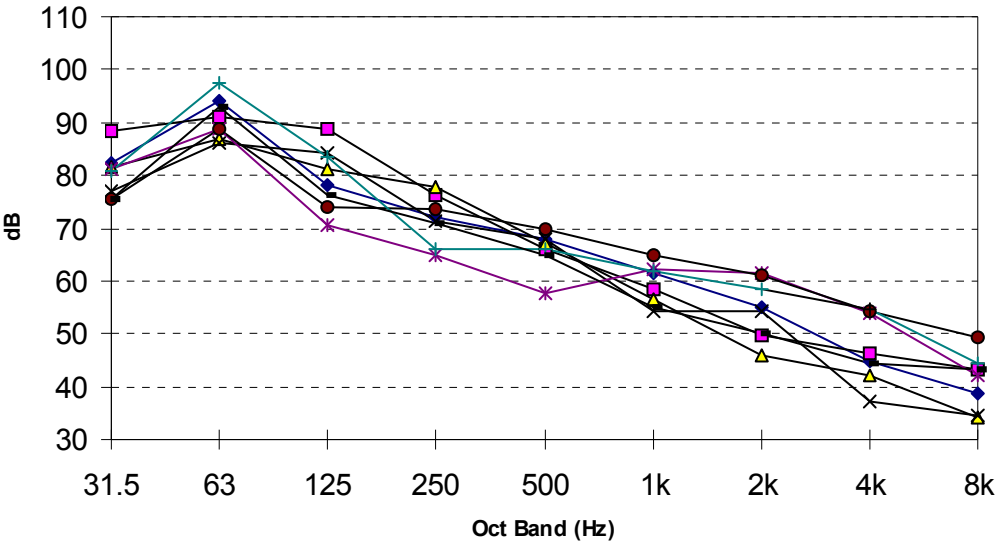

Figure 2 Exterior Sound Pressure Levels at 7.5 metres from Eight Vehicles, based on an interior level of 100 dBA.

Averaging these results indicates a significant increase of 9 dBA in maximum sound levels due to car audio at low speeds (35 km/hr), with smaller increases (<2.5 dBA) at 50 and 75 km/hr. Further testing was carried out using the same test arrangements but with the passenger side window completely open (facing the microphone position), and a separate test on two vehicles with the "sun roof" partially open (all other windows closed). These results are shown in Table 3.

Summary

Results of sound level measurements of typical stationary vehicles fitted with high power car audio systems (operating at 100 dBA internally) result in measured maximum sound levels at 7.5 metres between 74 and 82 dBA. These same vehicles (with audio systems operating at the same levels) result in 35 km/hr pass-by maximum sound levels of between 67 and 75 dBA. The lowering of sound levels during pass-by (compared to stationary) was unexpected, however it may be explained by reduced panel resonances when vehicles are under power, reduced sound propagation due to moving point source, or an artifact of using L_{max} as the measurement unit when the source sound (recorded music) varied in level over time.

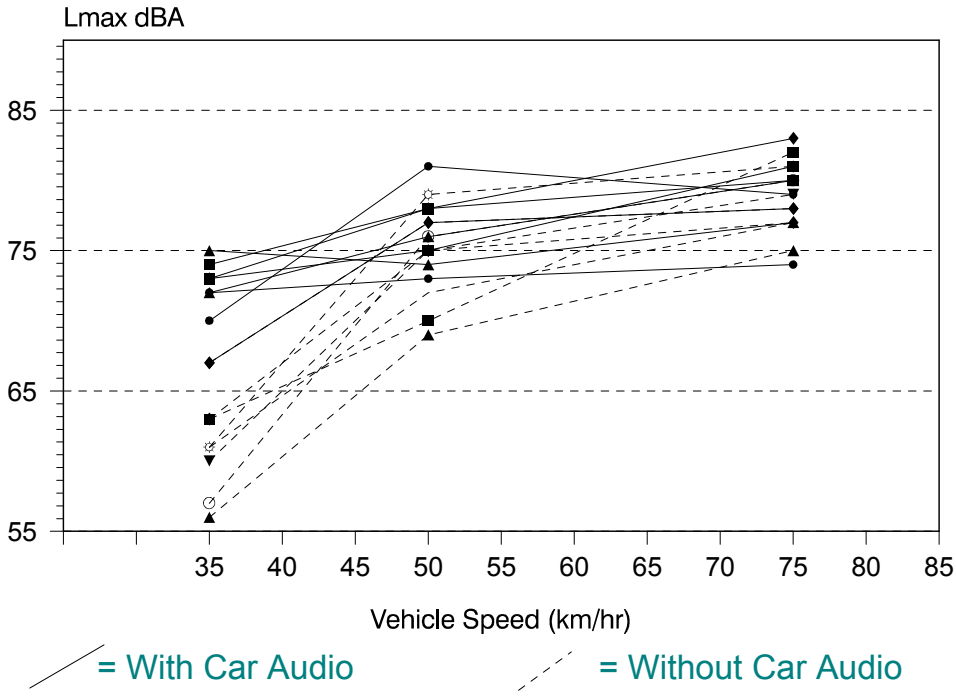

Figure 3 Maximum pass-by sound pressure levels with and without car audio operating.

An important feature of the measured exterior sound levels was the predominantly low frequency nature of the sound. Such sound is likely to be more noticeable than other typical vehicle sounds

	Without Audio	With Audio		
Speed		All Closed	Psngr. Window Open	Sun roof open
35 km/hr	61 dBA	72 dBA	93 dBA	89 dBA
50 km/hr	74.125 dBA	76.5 dBA	94.5 dBA	91.5 dBA
75 km/hr	78.625 dBA	79 dBA	96 dBA	93 dBA

Table 3 Average Maximum Pass-by Sound Levels, with and without Audio System Operating at 7.5 metres.

due to its temporal and spectral characteristics. Such sounds could also be more annoying as they may more easily penetrate buildings in the vicinity of roads.

Tests at pass-by speeds of50 and 75 km/hr with all windows closed, indicated the influences of tyre/ road noise and exhaust noise on L_{max} values. When the passenger side window is opened significant increases are evident. Such levels are consistent with heavy vehicle pass-by sound levels [2].

The main finding is that (with all windows closed) exterior vehicle noise levels can be increased by nearly 10 dBA during slow speed driving in typical urban situations. There are also minor influences at higher speeds. The effects of individual vehicles operating high power audio systems in the traffic stream is likely to increase instantaneous traffic noise levels, but have a negligible effect on overall 24 hour traffic noise levels due to the minor proportion of such vehicles. There is anecdotal evidence to suggest such systems are becoming more popular. The indications are that such systems may need to be controlled by regulation, and that type testing of noise from vehicles (eg. ISO R362, [3]) may have to specifically exclude external audio noise.

References

1. Beguet, B. & Chauray, J.L. Identification of Transmission Path In Interior Acoustical Problems, Inter-Noise 92 (p.1091-1094).

2. Sandberg, U. Noise Emission From Heavy Trucks Meeting the 84 and 80 dBA Limits, Inter-Noise 92 (p.829-834).

3. ISO362-1981 Acoustics - Measurement of noise emitted by accelerating road vehicles. Engineering method. ❑