Standardized automotive audio measurements

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Abstract: Since 2020, the Audio Engineering Society Technical Committee on Automotive Audio (TC-AA) has worked on developing an equipment specification and test methodology for in-car acoustic measurements that will ensure repeatable measurements, allow comparisons, and improve interpretation of results. This will make system-level specifications and requirements more meaningful and facilitate alignment between vehicle manufacturers (OEMs) and Tier 1 suppliers. In this paper, the TC-AA recommendations are demonstrated. The same test configuration is then used to demonstrate an extended suite of measurements that provides a more complete characterization of automotive audio. Measurements demonstrated in this paper include frequency response, seat-to-seat spectral uniformity, THD, intermodulation distortion, overall Max SPL, Max SPL at 10% distortion, and impulsive distortion.
Keywords: automotive audio, in-car acoustics, Max SPL, frequency response, impulsive distortion

0 INTRODUCTION

In this paper, we present a suite of automotive electroacoustic measurements based on the recent AES Technical Committee on Automotive Audio (TC-AA) White Paper. This includes measurements outlined in the White Paper, as well as additional measurements that more completely characterize car audio quality and performance.

The TC-AA White Paper[1] is a document produced by the Audio Engineering Society (AES) Technical Committee on Automotive Audio. The TC-AA believes that published guidelines and standard measurement procedures with well-documented measurement conditions will ensure repeatable measurements, allow comparisons, improve interpretation of results, and make system-level specifications and requirements more meaningful. This will facilitate alignment between vehicle manufacturers (OEMs) and Tier 1 suppliers.

A Working Group within TC-AA was formed in 2020 to create recommendations for making in-car acoustic measurements. The group included experts from a diverse range of companies

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including automotive manufacturers, infotainment system providers, and test and measurement equipment suppliers. It also included an advisory subcommittee that focused on the details of the measurement microphone array. The group published a White Paper in Oct 2023 and is encouraging anyone involved in in-car audio measurements to use these guidelines and provide feedback. This will assist in further developing the measurement recommendations, and the group hopes that this work will lead to standardized measurements in the future.

In this paper, the TC-AA recommendations are summarized with particular attention to the equipment, environment and settings. Next, the various stimuli used in the measurements are explained and the test configuration described. A range of system performance and vehicle integrity measurements is then demonstrated. These include frequency response, spectral uniformity, distortion, Max SPL, Impulsive distortion and more.

1 TC-AA White Paper Summary

1.1 Scope

The TC-AA White Paper covers system-level measurements in a stationary car, focusing on the basic measurements commonly used in the industry. It does not cover subjective assessment, component measurements, or measurements needed for sound tuning, although often the same tools can be used to make these additional measurements. It outlines the test environment, audio system settings, microphone position, test stimuli, measurement tools, and the measurements to be made. These are summarized below and will be discussed in more detail relative to the specific tests later.

1.2 Measurements

The White Paper details measurement methods for frequency response, maximum SPL and impulsive distortion.

1.3 Measurement Equipment

1.3.1 Measurement Software

The White Paper does not tightly specify the measurement software, stating only that it must be able to measure calibrated overall sound levels in dB SPL; A-, C- and Z-weighted as described in IEC 61672[2], and versus frequency. The sound measurement system must be capable of taking the independent signals from a 6-microphone array and power averaging them to measure a 30-second Leq, the level that if it had been a steady level during the measurement period, would represent the amount of energy present in the measured, fluctuating sound level. It must also be able to display results in standard 1/3rd octave bands[3].

This makes a software-based system an attractive choice due to the power-averaging calculations needed. Software-based systems also offer many other advantages over simple sound level meter tools as they can trigger test signals without a person in the car, automate much of the process, and carry out any calculations needed, displaying the results in clear graphical format. Furthermore, they generally offer a much greater range of capabilities and flexibility, enabling use in many other automotive audio measurements.

An audio interface suitable for powering and converting the microphone signal input to the computer for analysis is also required. Other hardware may also be needed, depending on the

method of playing the test signal. For example, if the signal is played via Bluetooth, a calibrated Bluetooth interface is also necessary.

1.3.2 Microphones and Microphone Array

In contrast to the fairly general guidelines on the measurement software, a sub-committee of the TC-AA developed extensive guidelines on measurement microphones, which are included in Appendix 1 of the White Paper. An array of six ¼" pressure field microphones is described. The microphones must be highly sensitive, with a good dynamic range, and a flat response over the audible frequency range. Table 1 details the recommended microphone specification.

Table 1: Microphone specifications for in-car audio measurement recommended by TC-AA.

Size	¼" microphone, less influence in the sound field
Type	Pressure, will in a car give the most accurate measurement due to the many sound sources inside the car
Sensitivity	A high sensitive microphone, with a low inherent noise is recommended, especially for distortion measurement
Dynamic Range	For a High sensitive microphone approximately from 25 dBA – 145 dB For a Low sensitive microphone approximately from 40 dBA – 166 dB
Frequency Range	For a High sensitive microphone approximately from 5 Hz – 20 kHz (2 dB) If signal is corrected up to 40 kHz For a Low sensitive microphone approximately from 5 Hz – 70 kHz (2 dB)

The six microphones must be numbered and mounted in the standard array configuration first proposed by Geddes and Blind in 1984[4] shown in figures 1 and 2. Figure 1 shows the numbering configuration relative to the car, and Figure 2 provides the precise dimensions and orientation of the array.

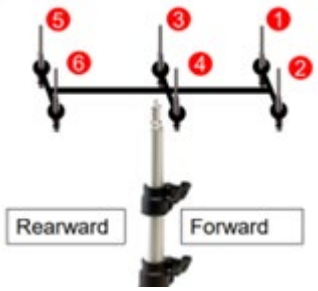
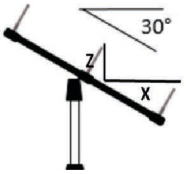


Fig.1 Microphone array recommended arrangement and numbering (courtesy of TC-AA).

Array Dimensions (cm)		
X	Z	Y
13.2	7.6	15
angle = 30°		



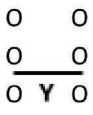


Fig. 2 Precise dimensions and orientation of the microphone array (courtesy of TC-AA).

1.3.3 Test Configuration

Figure 3 shows a typical software-based test configuration for making measurements in line with the TC-AA recommendations. The test signal is played through the speakers and captured by the 6-microphone array. The captured response is converted via an audio interface and input to analysis software on a computer, where the results are processed in line with the specifications.

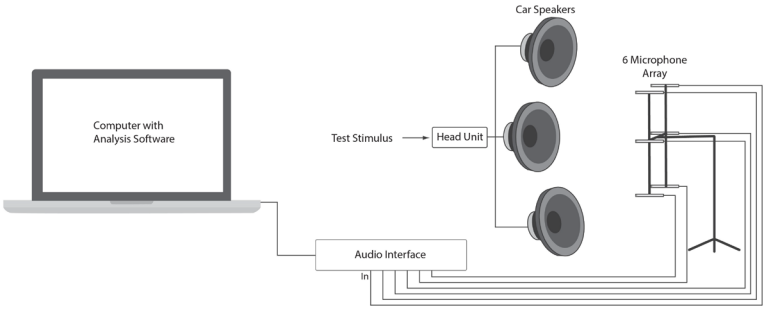


Fig. 3 Test configuration for making automotive measurements with a software-based system.

1.3.4 Playing test signals from the car's head unit

One of the significant logistical challenges in automotive measurements is getting the test signal into the head unit to play out of all the loudspeakers in the car. The paper does not specify a playback method, simply stating: "The excitation can be played back from any variety of well-documented sources including a memory stick, CD, file on the head unit, Bluetooth connection, or auxiliary line-in". It also requires that the chosen method is described in the documentation. Three methods are commonly used: memory stick, Bluetooth, and via the cloud. These configurations are demonstrated below using Listen's software and hardware products.

Figure 4 shows the test configuration using Bluetooth to transmit the signal to the head unit. In many cases this is the most convenient method as it does not rely on proprietary access to the car's head unit. It also enables control of the playback via the test software, which makes it easier to do remotely. The downside is that it requires an additional piece of hardware, a Bluetooth interface. Note that it is essential to use a high-quality calibrated Bluetooth interface that is designed for audio testing and allows precise control of the codec selection and test level.

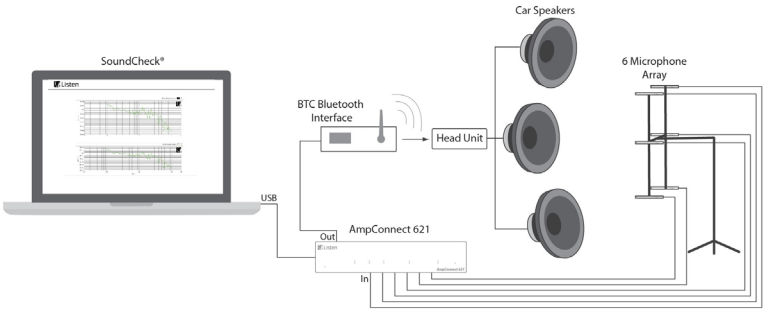


Fig. 4 Automotive measurement configuration with Bluetooth transmission.

Figure 5 shows the configuration required to play back the test signal via a memory stick. While simple, not all cars have a USB input. It also requires someone to be in the car to start the test stimulus then rapidly exit before measurements begin to avoid exposure to high volume pink noise or test tones. This adds complexity to the measurement process.

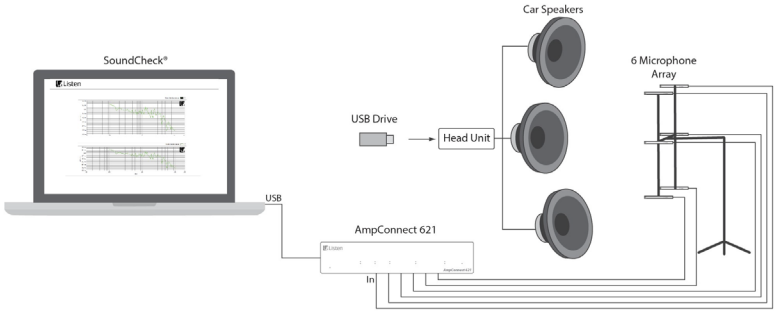


Fig. 5 Automotive measurement configuration with USB Input.

Figure 6 shows the test configuration for playing the test signal via the cloud. In this case, either the internet connected in-car music application, or a phone with Android Auto or Apple CarPlay is used to play the test stimulus from a streaming service. This requires additional setup, for example hosting your test stimuli in the cloud.

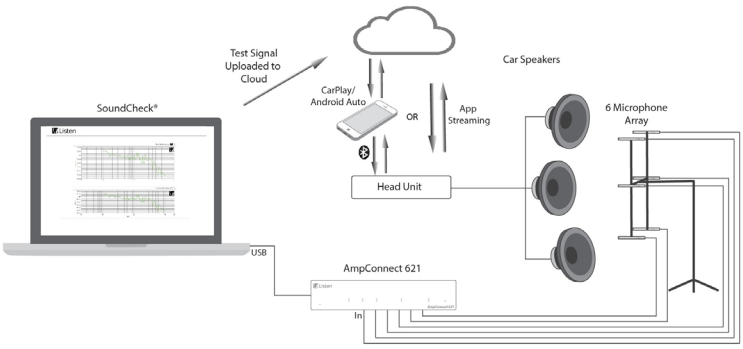


Fig. 6 Automotive measurement configuration with input via the cloud.

1.4 Measurement Conditions

1.4.1 Microphone Placement

Consistent microphone placement is critical for repeatable measurements. The goal is to place the array in the position that best represents the median position for combined male and female adult humans. While OEMS and Tier One suppliers may have access to detailed head location data for their vehicle, this is not universally available. The White Paper therefore provides two alternative methods for positioning the 6-microphone array.

The first option relies on using head location (eyellipse) data. In this case, the center of the array is placed at the median head location for the specific vehicle, or other internal reference, and the point expressly documented with the data set.

Where head location data is not available, the center of the array is positioned at the ear position where a median person would sit comfortably. The White Paper suggests a distance of 740mm from

the seat and an angle of 30° from the horizontal as shown in Figure 7. The position of the array must be documented relative to a set of fixed points in the interior (steering wheel, dashboard points, b-pillar, etc.). This might, for example, include the position in the driver's seat relative to the center, backrest and height, the inclination of the backrest, and the distance between the seat and the pedal. Measurements should be taken in the driver's seat and in at least one seat position in each row.

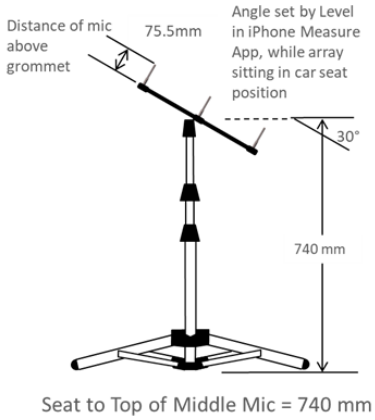


Fig. 7 Height and inclination of microphone array (courtesy of JJR Acoustics/TC-AA).

1.4.2 Test Vehicle and Environment

Measurements should be made in a stationary car in a suitable quiet test area, for example a garage or test bay. All doors and windows must be closed when making measurements.

1.4.3 Audio System Settings

All user accessible audio settings (e.g., tone controls, faders, etc.) including EQ and spatial settings must be set to default or factory reset. In most systems, this is neutral or flat. All audio settings should be documented.

2 Test Stimuli

Test Stimuli are defined for each test. The White Paper suggests a pink noise stimulus for measuring frequency response and Maximum SPL, and a sinusoidal logarithmic sweep for measuring impulsive distortion. If alternate stimuli are used, they should be accurately described in the measurement report. In this paper, a more extensive set of test signals is used to more completely characterize the audio system's performance. These test stimuli are summarized in Table 2.

Table 2 Test stimuli used in automotive audio testing

Stimulus	Details	Application
Correlated Pink Noise*	Unclipped monophonic (L+R same) full-scale pink noise signal (CPN) rms level approx. -12 dBFS [5] Crest factor of approx. 15 dB	Frequency Response, Max SPL
Uncorrelated Pink Noise	Unclipped uncorrelated (L+R randomized) pink noise signal (UPN) full-scale pink noise signal	More realistic (music-like) Frequency Response at low frequencies
Out of phase pink noise	Unclipped L+R (180 deg inverted) pink noise signal (UPN) full-scale pink noise signal	L&R cancellation indicates a well-matched system
Sine sweep*	Continuous logarithmic or 1/24th octave stepped sine sweep from 30 – 1kHz at -12dBFS	Impulsive Distortion for checking vehicle integrity
Stepped Sine sweep	1/12th octave stepped sine sweep from 20Hz-20kHz at -12dBFS	THD
Two-tone Sine sweep	1/12th octave Stepped sine sweep from 150Hz-20kHz, -12dBFS and Fixed tone at 50Hz at -3dBFS	Intermodulation Distortion, checking for multiway system with crossovers
Tone bursts	50 cycle tone burst at discrete frequencies typically in 1/3rd Octave steps with increasing level until the maximum specified THD level is reached	Looking for dynamic performance of the infotainment system e.g. Max usable SPL, compressors, etc.
* recommended in TC-AA White Paper		

3 Practical Test Configuration

A suite of measurements was performed on a modern electric sports utility vehicle. In line with the paper's recommendations, the measurements were made in a quiet underground parking garage.

The test configuration shown in Figure 4 was used. The Bluetooth connection option was chosen for simplicity and its ability to integrate stimulus playback with the test sequence for more automated measurements. Listen's SoundCheck audio test system performed the analysis, and Listen's AmpConnect 621 audio interface was used to transmit the microphone responses to the software. A BQC-4149 Bluetooth interface provided the connection to the car's head unit. This configuration is used for all measurements presented here.

SoundCheck is a full-featured and flexible audio test system capable of making all the measurements outlined in the White Paper. Of specific note is its ability to power average the inputs from the 6 microphones in ISO standard 1/3rd octave bands[3] that is required for most of the measurements. The AmpConnect 621 audio interface supports 6 microphone inputs and has a wide dynamic range with autoranging which helps ensure a good signal to noise ratio for more accurate measurements. The BQC-4149 is a small, portable Bluetooth interface that integrates fully with SoundCheck. This allows the stimuli generated within a test sequence to be wirelessly transmitted to the car's head unit for playback through the speakers. Note that it is critical to use a test-grade Bluetooth interface with an A2DP codec for the best frequency response and signal to noise ratio.

The microphone was positioned following the guidelines in the AES white paper. It was set to a height of 74cm with a 30° angle, centered in the driver's seat with the microphone stand legs positioned against the back of the driver's seat. The distance between the closest microphone and the headrest was 10cm and the brake pedal to backrest distance was 100cm.

4 Calibration

Before making any measurements, both the inputs and outputs of the test system were calibrated by measuring the sensitivity of each individual microphone in the array with a B&K 4231 acoustical calibrator and storing these readings in the software calibration menu. Acoustical calibration is

preferred over reading TEDS (transducer electronic data sheet) data as it accounts for actual measurement conditions including temperature and cabling losses. The audio interface was also calibrated to ensure proper response frequencies and levels, both in the analog and digital domains.

5 Measurements

5.1 System Characterization Measurements

5.1.1 Frequency response at 80dBA with correlated pink noise

Frequency response is the clearest indicator of overall performance. If frequency response is outside the limits, the tonal balance is affected and the audio system may not sound as intended.

Measurements were made using a SoundCheck test sequence following the White Paper recommendations. The frequency response was measured at 80dBA using monophonic, correlated pink noise on both left and right input channels on the head unit. 80dBA was chosen as the test level because it is a typical listening level in the car and usually the head unit does not employ loudness compensation (equalization boost at the lowest and highest frequencies) at this level.

First the system was calibrated to ensure that the head unit's volume control was set to the correct level for a power average of 80dBA of all six microphones. The test sequence then prompted the user to enter the car model and seat position to ensure that the data was recorded with the measurement. Next, the stimulus played for 30 seconds and the response was captured by the six microphones. The test system measured and compensated for any delay between the output test signal and the acoustic input signals to the microphones. Delay compensation is critical to making accurate measurements as such delays can be significant; one car that was measured had an astonishing 1.35s delay from Bluetooth output to measurement microphone input.

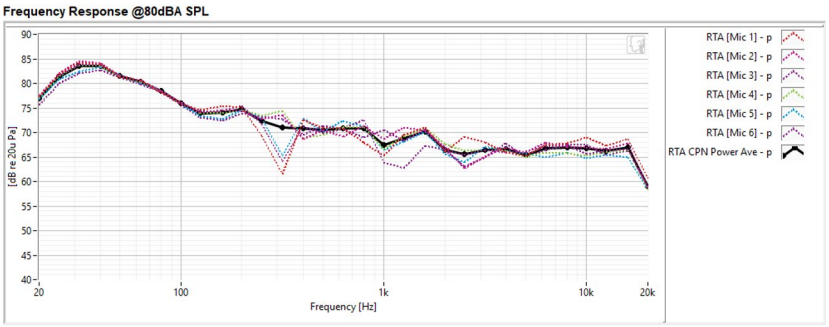


Fig. 8 Frequency Response Curves for each array microphone with Pink Noise @ 80 dB(A) and calculated Power Average Response of all 6 microphones.

5.1.2 Frequency response at 80dBA with uncorrelated pink noise

Next, frequency response was measured with *un*correlated pink noise at 80dBA. This test was identical to the previous measurement, except that uncorrelated pink noise was randomized between the left and right channels rather than playing the same pink noise out of the left and right channels.

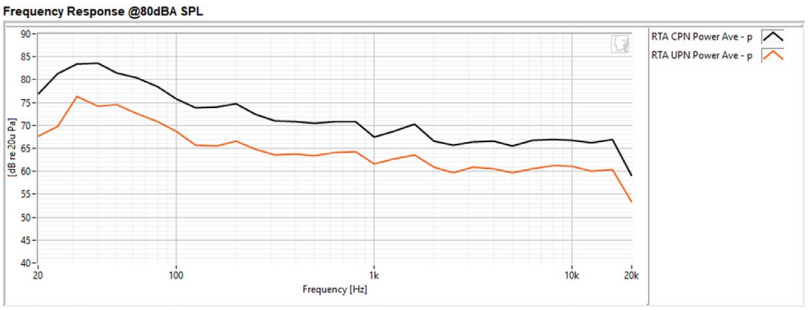


Fig. 9 Power Averaged Frequency Response Curves for both Correlated and Uncorrelated Pink Noise @ 80dB(A).

Figure 9 shows the results with *un*correlated pink noise (UPN), the orange line plotted on the same graph as the spatial average with correlated pink nose (CPN), the black line. These results show that the uncorrelated pink noise has less output than the correlated pink noise, about 6dB above 1 kHz and 8 to 11dB below 1 kHz. It is surprisingly uniform and indicates a well-matched system.

5.1.3 Seat-to-Seat Spectral Uniformity

Ideally each passenger in the car experiences the same high quality sound performance from the infotainment system. However it is extremely difficult to independently equalize the loudspeaker playback system for each seat in the car. Trade-offs are made in the tuning of the infotainment system, typically favoring the driver's seat. This results in the frequency response in the other seats being not as smooth or ideal.

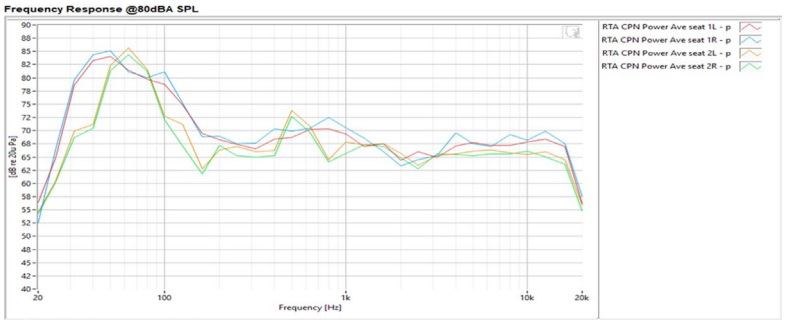


Fig. 10 Power Averaged Frequency Response at each of the 4 Seats.

The same measurement with correlated pink noise was repeated in each of the car's four seats, and the measurements compared. Figure 10 reveals that the bass performance in the rear passenger seats (orange and green lines) is not as extended or smooth as the front passenger seats. The seat-to-seat spectral uniformity (Figure 11) is calculated by comparing the individual seat response to the maximum and minimum responses and finding the seat with the biggest difference. In this example, both the left and right rear passenger seats have over 10dB difference from the front seats at some frequencies. The lower the number the more uniform the frequency response is from seat-to-seat.

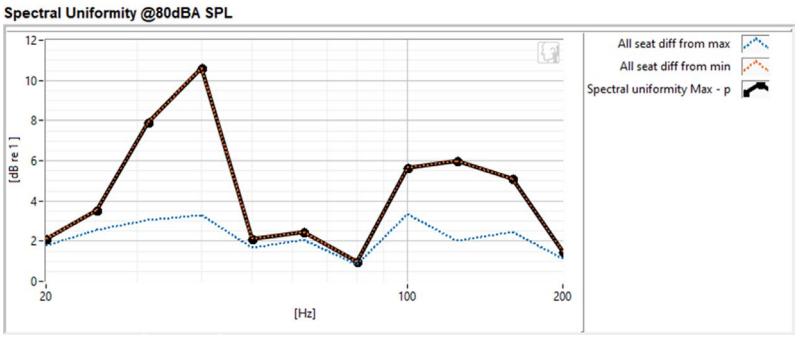


Fig. 11 Seat-to-Seat Spectral Uniformity @ 80dB(A).

5.1.4 THD at 80dBA

THD indicates the overall non-linear performance of the device. If the THD is outside the limits, it may indicate a poorly centered voice coil, or mechanical defects. The Total Harmonic Distortion was also measured at 80dBA, this time using a stepped sine sweep stimulus with 12th octave steps. There was some averaging at each frequency step to minimize background noise but not for long enough for the system's compressors to activate. The sine wave was swept from high to low because it generally achieves more consistent results than sweeping from low to high. This is because the compressors do not activate as quickly and the speakers ring for a shorter time than they would if hit with a high level, low frequency step at the beginning of the sweep.

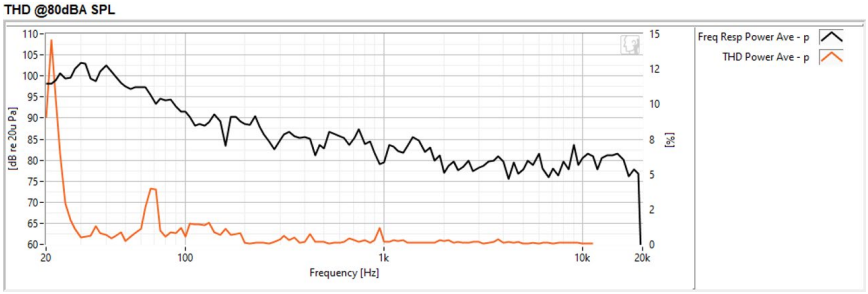


Fig. 12 THD @80dBA SPL.

As before, the spatial average of all six microphones was power-summed to produce the THD power average curve shown in Figure 12. This smooths out the standing waves and reflections picked up by the individual microphones. In this case, the THD is not too high - roughly 2.2% from 50 Hz to 10 kHz.

5.1.5 Intermodulation Distortion

Intermodulation distortion is a good test for multi-way speaker systems with a crossover. If a small driver is trying to play back low and high frequencies simultaneously, it will struggle to play both frequencies and create intermodulation distortion.

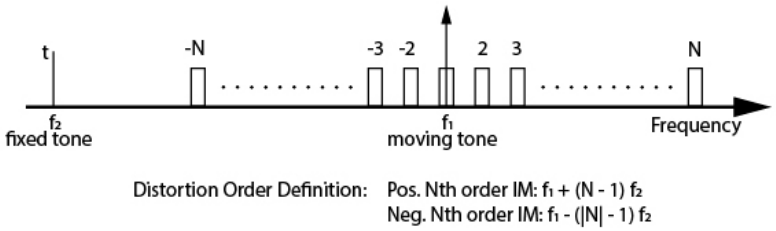


Fig. 13 Intermodulation Distortion

Intermodulation distortion measurements[6] use a two-one stimulus with a fixed tone at a low frequency and a sweeping tone (Figure 13). The fixed tone, F2, is set to 50 Hz, typically in the subwoofer frequency range. The precise value is not important, but it should be near the speaker's resonance and below the crossover frequency. The master tone, or sweeping tone, F1 sweeps high to low from 20 kHz down to 150 Hz for measurement stability. Typically, the sweeping tone stops at around 3 times the frequency of the fixed tone to avoid their respective tracking filters from overlapping and resulting in measurement errors.

Our test sequence first swept from 20 kHz to 200 Hz to ensure the auto-delay was correctly set and to auto-range the input gain for the best signal to noise ratio. Distortion harmonics can be as much as 60dB below the fundamental and still be audible, so it was important to maximize the measurement system's dynamic range by adjusting or auto-ranging the input gain for a signal to noise ratio where the harmonics were above the noise floor of the measurement. The intermodulation distortion stimulus described above was then played, and the responses power-averaged and displayed.

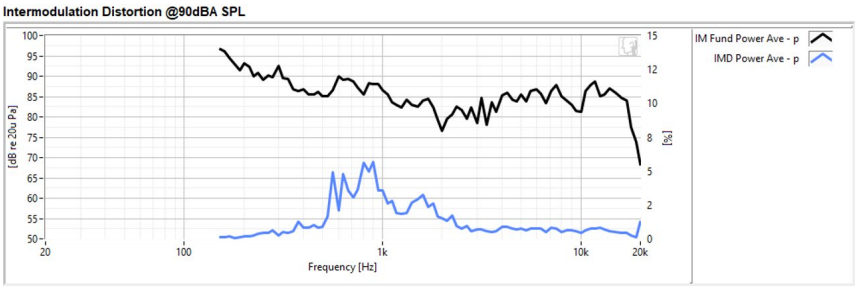


Fig. 14 Intermodulation Distortion @90dBA

Figure 14 shows the fundamental and total intermodulation distortion of the 2nd and 3rd order intermodulation products, power averaged from the 6-microphone array. As expected, the intermodulation distortion is higher at the lower frequencies but there is also an increase around 1.5 kHz which is probably a crossover frequency in this car. Taking the power average of all six microphones results in an overall average level of 2% intermodulation distortion.

5.1.6 Maximum SPL

Both manufacturers and consumers want to be able to compare the maximum volume of an infotainment system in a car. Manufacturers like to quote this in specifications; consumers like to

brag about whose car stereo plays the loudest.

Maximum SPL is defined as the maximum sound pressure level that a car's infotainment system can reproduce inside the car's cabin with its windows, sunroof, and convertible top closed. This measurement combines all the components of the system - speakers, amplifiers, power supply etc.

There are many ways that this can be measured, but to keep it simple, the TC-AA committee recommends two different measurements: overall Max SPL, and Max SPL spectrum regardless of distortion level. After considerable debate, the TC-AA working group decided that distortion should not be taken into account when measuring the max SPL spectrum because modern-day infotainment systems are so loaded with signal processing, e.g. compressors, limiter etc. that it is very challenging to characterize.

For this test, the volume control of the infotainment head unit was set to maximum. Overall Max SPL and SPL spectrum were measured simultaneously using a broadband 20 to 20 kHz, -12 dBFS monophonic pink noise stimulus with a crest factor of 12dB. The stimulus was played for 30 seconds to ensure that the level could be sustained continuously. The results are shown in Figure 15.

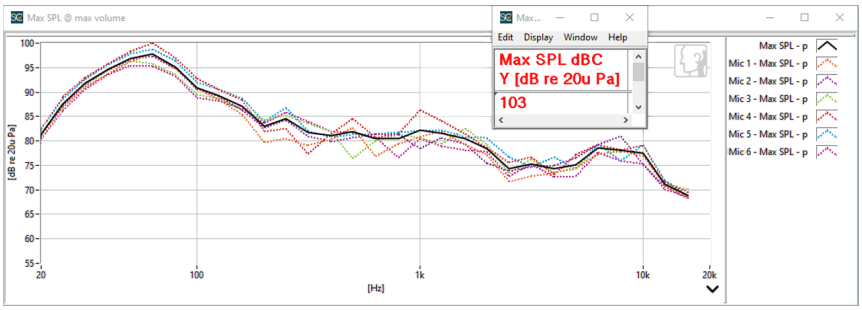


Fig. 15: Max SPL 1/3rd Octave Spectrum and Overall Max SPL.

The overall level of 103dBC, regardless of distortion, is not too loud but may be limited by design to prevent severe distortion at low frequencies from clipping the amplifier.

5.1.7 Maximum SPL @10% THD

It can be argued that defining the Maximum SPL should be based on the onset of audible distortion. Since compressors and limiters have a time constant to allow for short term transient peaks typically found in music, it is possible to measure the Maximum SPL and distortion before they take effect. THD can be measured relatively accurately without damaging the speaker at high test levels using a short tone burst, for example, 50 cycles which is 500ms long at 100 Hz and 50ms at 1 kHz.

For each measured frequency, the test sequence played the stimulus multiple times, increasing the level in 3dB steps until the THD exceeded 10%. The level was then reduced by 3dB and increased in smaller increments of 0.5dB to more precisely find the 10% THD threshold. The Max SPL was recorded at that frequency and the test sequence continued to the next frequency, e.g. the next 1/3rd octave frequency. The entire process was completely automated via the test sequence, making this measurement considerably faster than with a test system that does not offer this capability.

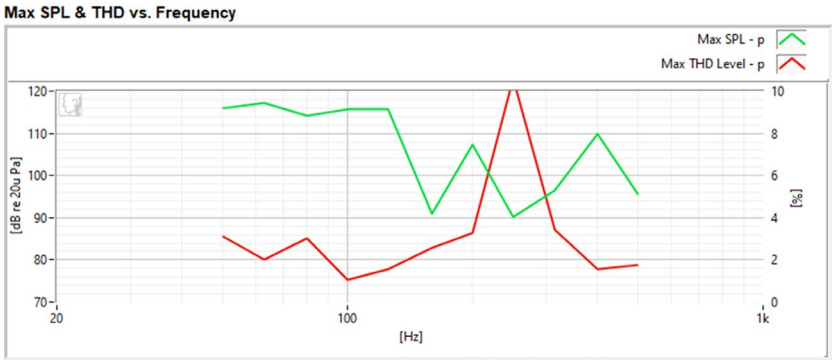


Fig. 16 Max SPL and Corresponding THD.

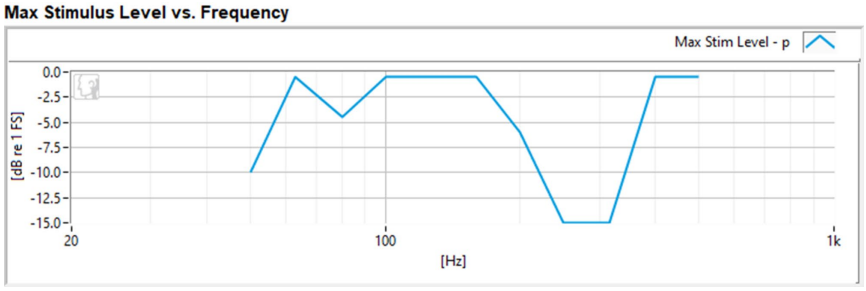


Fig. 17 Max Stimulus Level.

Figure 16 shows the Maximum SPL and corresponding THD. When the THD reaches 10% or the Maximum Stimulus Level with the head units' volume control set to max, as shown in Figure 17, the SPL is plotted. At some frequencies, especially higher frequencies, for example 400 Hz and 500 Hz, the maximum input level is reached before the system distortion reaches 10% THD. The stimulus level is typically limited by the lower frequencies where there is more distortion. Since it is debatable how audible THD is, it is possible to use other criteria such as Rub & Buzz distortion which is quite audible to find the Max SPL limit.

5.2 System Integrity Measurements

5.2.1 Impulsive Distortion

Infotainment system sound quality is sometimes limited by vehicle integrity, for example the speakers may cause door panels, loose wire harnesses, fasteners, etc. to vibrate. This results in audible Buzz, Squeak and Rattle which degrades the listener experience. Before performing the system characterization measurements described above, it is a good idea to ensure the infotainment system is properly installed in the vehicle under test. This can be achieved by measuring impulsive distortion. This test may also be used as an end-of-line check to verify vehicle integrity.

The AES White Paper recommends using a crest factor measurement with a logarithmic sine sweep and a tracking high pass filter, ten times greater than the stimulus frequency, to evaluate impulsive distortion at 80 and 90dBA. The Crest factor is the ratio of Peak level to RMS level. A sine wave has a crest factor of 3dB. Pink noise has a crest factor of about 12dB. Transients, e.g. rattling wires, loose fasteners, and noise, e.g. background noise, have a crest factor typically greater than 8dB. A crest factor greater than 3dB, may indicate buzz, squeak or rattle. However, background noise, especially in a noisy factory may cause similar Crest Factor results, so care must be taken to

minimize background noise and ensure that the results correlate with what is heard. Since there was no audible or measurable Buzz, Squeak and Rattle at 80dBA in this car, it was re-measured at 90dBA where the distortion became audible. It is also more visible in the crest factor measurement (Figure 18), especially between 200 - 300 Hz.

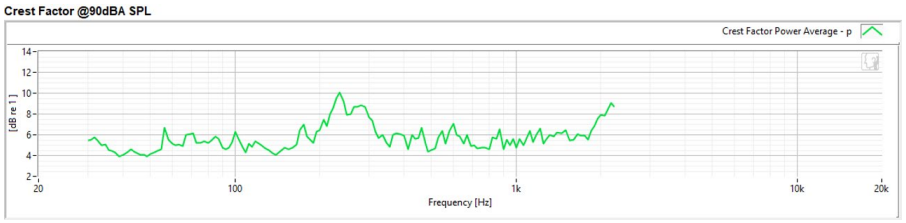


Figure 18: Crest factor of impulsive distortion at 90dB SPL

The test sequence also simultaneously measured Perceptual Rub & Buzz and transient distortion versus time. Perceptual Rub & Buzz measurements use masking curves to simulate the performance of the human ear to measure only audible distortion. This measurement technique offers a couple of advantages over a crest factor measurement; it is less sensitive to background noise, and it only highlights Rub & Buzz sound that is audible to humans.

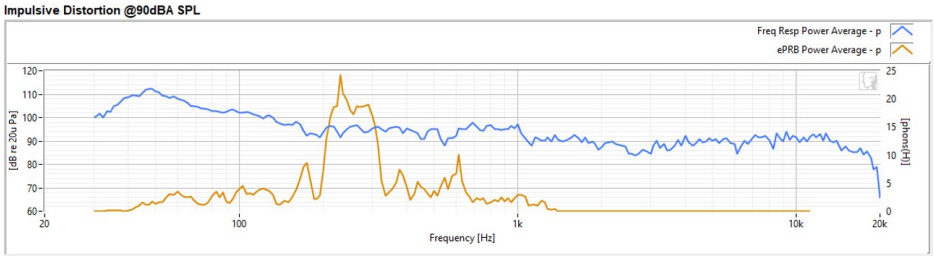


Figure 19: Fundamental response and perceptual Rub & Buzz for at 90dB SPL

The Perceptual Rub & Buzz results in Figure 19 show a noticeable bump around 200 Hz to 300 Hz and a smaller, sharper bump at 600 Hz which is not obviously present in the crest factor measurement. These were clearly audible during the sweep.

The transient distortion versus time measurement reveals any loose particles or rattling wires in the car with greater precision than frequency response since it tracks individual events. Crest factor, which is a running average, will smooth out some of the transients by the very nature of its calculation.

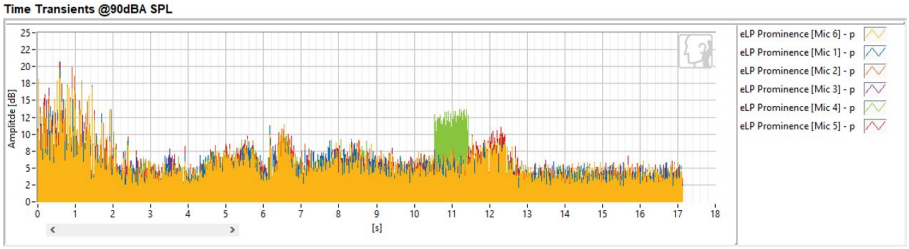


Fig. 20 Time transients of impulsive distortion at 90dB SPL.

Figure 20 shows the time transients of the impulsive distortion measurement. Analyzing impulsive distortion in the time domain displays the constant background noise as a steady noise floor and impulsive distortion is highlighted as well-defined transient spikes. In Figure 20, transient spikes from measurement microphones #4 and #5 are clearly observed around 11-12 seconds into the sweep. These are closer to the driver side door where some door panel rattling is occurring at low frequencies around 200-300 Hz in the sine sweep.

6 Conclusions and Future Work

Measuring vehicle infotainment systems is becoming more and more complex. An ever-increasing number of speakers are being installed in the car at various locations including the headrest and ceiling. There is more and more signal processing, for example, Dolby Atmos. Vibration exciters are even being added in the seats of some cars to extend bass response. As a result, more sophisticated and flexible measurements are needed to keep up with the advancements in infotainment systems. This will necessitate acoustical, vibration, electrical and psychoacoustics measurements to be made to correlate measurements to human perception of sound inside a vehicle.

Nevertheless, it is important to develop standardized measurements like the AES White Paper recommendation, to make it easier to compare performance of different vehicle audio systems. Calibrated measurements of frequency response, distortion and maximum SPL with a six microphone array as outlined in the AES White Paper is a good foundation for objectively analyzing the performance of the vehicle's infotainment system. Impulsive Distortion measurements are an effective way to ensure the vehicle's build integrity before making car audio measurements.

The TC-AA White Paper is currently in the review period. The group hopes that automotive audio engineers worldwide will make measurements in line with the methods in the white paper and provide feedback. This will drive updates to the measurements and methodology to ensure that the methods are practical for most manufacturers. It is hoped that these measurements will eventually lead to the development of an industry standard. The equipment configuration used in the TC-AA measurements is also suitable for many other automotive audio measurements, making it easy to further develop and customize in-car audio measurements.

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