# DRAFT PROPOSED Test Procedure for Pitch Shifting

**Note: This document is "In progress" and many items can be expected to change prior to final approval.**

Scope

This measurement quantifies the acoustic characteristics of an external sound generation system. Such a system includes, but is not limited to, the sound generation device, the power unit or amplifier for the sound generation device, and the control unit which provides the acoustic signal to the sound generation device or amplifier, and any necessary equipment for simulating vehicle input signals to the control unit which are used by the control unit to determine the acoustic signal.

This test is intended to measure the change is frequency of a external sound generation system as a function of velocity for a vehicle.

NOTE:. The intent of the analysis is to extract information on the sound characteristics which can provide useful information to pedestrians to enable pedestrians to make safe travel decisions.

## 1. DEFINITIONS

## 2. SYMBOLS AND ABBREVIATED TERMS

## 3. INSTRUMENTATION

### 3.1 Microphone

The microphone used shall fulfill the requirements to be used in an IEC 61672 Class 1 sound level meter. In addition the dynamic range of the microphone shall be at least 20-100 dB.

### 3.2 Digital Sound Recording System

The entire acoustic measurement system including microphone(s) and any subsequent measurement apparatus shall fulfill the requirements of IEC 61672 Class 1 sound level meter. The digital sound recording system shall have at least a 16 bit quantization and a minimum sample rate of 44.1kHz.

### 3.3 Signal Processing Criteria

The frequency resolution of the measurement shall be at least 1 Hz. The frequency range of measurement shall be at least 20 – 20,000 Hz.

The sound analysis system shall be capable of performing Discrete Fourier Transform and Auto Power Spectrum analysis at a resolution of at least 1 Hz and over the frequency range containing all frequencies of interest.

Analyzer settings shall be determined by the user to provide data according to these requirements.

## 4. ACOUSTICAL ENVIRONMENT

### 4.1 Facilities.

The test facility shall provide anechoic or hemi-anechoic characteristics to a frequency equal to or lower than the lowest frequency intended to be measured. Background noise is considered to include room or test cell ambient noise and room support equipment noise. The room shall provide a background sound pressure level of at least 15 dB less than the sound pressure level of the device under test. Where measurements are made using loudness, the room shall provide maximum Zwicker specific loudness (DIN 45631, free field, frequency scale in Bark) of the background noise is not to exceed 0.2 sones/bark from 0 to 5 bark, and 0.1 sones/bark at any frequency greater than 5 bark, and the overall Zwicker loudness is not to exceed 1.2 sone GF.

The test facility shall meet the requirements of paragraphs 6.1.1 or 6.1.2 of SAE J2889-1

## 5. TEST PROCEDURE

The pitch shift may be measured by either a vehicle or a component based test procedure.

### 5.1 Component test procedure

The loudspeaker component of the ESG system shall be mounted 0.5 m above the reflecting plane (floor) of the test space and the primary propagation axis of the speaker shall be oriented horizontal to the reflecting plane.

The microphone shall be located 1.0 m from the center of the device at a height of 0.5 m.

Identify a dominant tone that exists for the entire duration of the event.

Note: Typical signal analysis tools provide frequency and time coordinates of the tonal component can be obtained by using a cursor on the color spectrogram to pick frequency and time coordinates that correspond with vehicle speed.

### 5.2 Vehicle test procedure

The vehicle shall be installed in an indoor test facility where the vehicle can operate in the same manner as outdoors. The test facility shall meet all acoustic requirements and have the capability to simulate actual road load input to the vehicle. All microphone locations shall be as defined in SAE J2889-1.

Identify a dominant tone that exists for the entire duration of the event.

Note: Typical signal analysis tools provide frequency and time coordinates of the tonal component can be obtained by using a cursor on the color spectrogram to pick frequency and time coordinates that correspond with vehicle speed.

### 5.3 Measurment procedure

1) The frequency characteristics of the ESG sound generated shall be measured with an input to the ESG system corresponding to the lowest vehicle speed as specified in Table 1. Measure the sound output of the system as follows: Record at least [5] seconds of the sound at a sample rate of at least 44.1 kHz. Using a [Hanning] window, calculate the autopower of the signal with a

frequency resolution of [1] Hz using at least [10] overlapping averages from the [5] second time signal.

2) (Alternative to #1) For each vehicle velocity, beginning at zero velocity, and continuing to the maximum velocity of system operation in [1 ] km/hr increments, measure the sound output of the system as follows: Record at least [5] seconds of the sound at a sample rate of at least 44.1 kHz. Using a [Hanning] window, calculate the autopower of the signal with a frequency resolution of [1] Hz using at least [10] overlapping averages from the [5] second time signal.

3) [Zwicker specific loudness (DIN 45631]?

4) The main frequencies, $f_{i,0}$, of the external signal shall be noted. At least one tone shall be identified for tracking as a function of vehicle speed.

5) The frequency shifting, *del_f*, shall be calculated as : $del\_f = (f_{i,vel} - f_{i,0}) / f_{i,0}$

6) The pitch shift, del_pitch, shall be defined as : $del\_pitch = 19.9371 * \text{Log}(f_{i,vel} / f_{i,0})$

Note: A difference of 0.5 scale-steps corresponds to the pitch interval of a half step (or semitone) in music, i.e. the smallest defined pitch interval in the equal tempered scale. On the piano a half step (or semitone) is the pitch interval from one key to the next adjacent key.

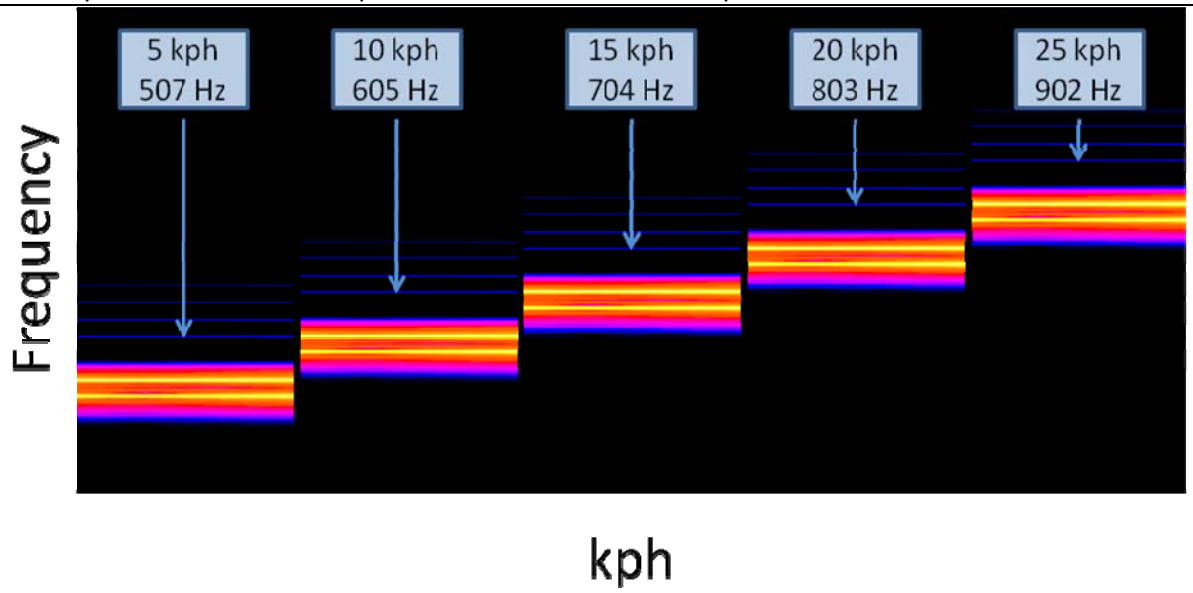
| **Target Velocity** | **Actual Velocity** | **Frequency** | **Frequency Shift** | **Relative Pitch Shift** |
|---|---|---|---|---|
| 0 km/hr or Motion Commencing | | | Defined as Zero | Defined as Zero |
| 5 km/hr | | | | |
| 10 km/hr | | | | |
| 15 km/hr | | | | |
| 20 km/hr | | | | |

Table 1. Vehicle speeds for measurement

**Appendix 1**

**Relative Pitch Calculation Example**

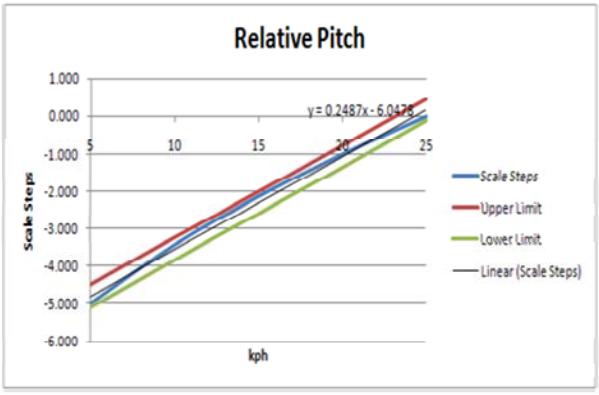
1. Identify a dominant tone and pick the coordinates for each speed measurement




2. Convert the frequency coordinates to scale steps and calculate the slope

| kph | Hz | Scale Steps | Slope | Upper Limit | Lower Limit |
|---|---|---|---|---|---|
| 5 | 507 | -4.993 | 0.249 | -4.504 | -5.104 |
| 10 | 605 | -3.451 | | -3.261 | -3.861 |
| 15 | 704 | -2.142 | | -2.017 | -2.617 |
| 20 | 803 | -1.005 | | -0.774 | -1.374 |
| 25 | 902 | 0.000 | | 0.470 | -0.130 |

Upper and lower limit values are based on +/- 0.300 variation from the slope




Scale Step Calculation Example
For 5 kph @ 507 Hz
19.9371 * Log (data value/max value)
19.9371 * Log (507/902) – -4.993 Scale Step