PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Using realistic test signals to evaluate existing structures for low frequency sound transmission from clubs, live music venues, discos, and exercise facilities.

David WOOLWORTH[1];

[1] Roland, Woolworth & Associates, United States

ABSTRACT

Low frequency sound used in entertainment (and sometimes exercise) facilities is difficult to reproduce in standard testing procedures for existing facilities such as ANSI E336 and ISO 16283-1, as the test cutoff frequency is well above sounds generated in-situ for these facilities, and some methods or loudspeakers cannot reproduce the sound level of low frequency that would be typical for everyday operation for these facilities This paper proposes using alternate test signals and methods that are appropriate to facility programming that must be isolated from neighboring structures. It addresses "worst case" low frequency source characterization, sound levels that incite vibration of finish materials that are transferred through the structure, and metrics used to evaluate receiving spaces.

Keywords: Pulse, Low Frequency, Isolation

1. INTRODUCTION

The advent of inexpensive low frequency sound reproduction in loudspeakers for music since the 1980's has made low frequency sound sources ubiquitous and in turn has changed the way popular music forms are recorded, mixed, and mastered to include more low frequency content. (1) This content is being manipulated by artists to create new sounds, in some cases with the goal of being louder or increasing the physical impact of the reproduction. This is especially prevalent in music forms such as pop, urban, electronic dance music (EDM), country music, and heavy metal (2); this music appears in exercise facilities, dance clubs, and live music venues among other places. The U.S. trend of mixed use lightweight and/or historical construction that combines these venues with residences or nearby residences can result in unwanted low frequency sound.

Samples of sound measured in residences and residential areas affected by low frequency sound from clubs are shown in Figures 1 and 2. There is significant energy below 50Hz that must be considered. What is also of interest is the low frequency content of operational sound levels is 15-25dB Leq above background sound levels.

2. TESTING AND TEST SIGNALS

2.1 Standards for Field Testing of Sound Transmission Loss

Two standards were examined for suitability to examine clubs for sound transmission inside the same structure: First, ISO 16283-1:2014 Field measurement of sound insulation in buildings and of building elements Part 1: Airborne sound insulation (3), which assesses the third octave band frequency range 50Hz to 5kHz, and second, ASTM E336-19 Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings (4), which addresses the minimum third octave band frequency range 125Hz to 4000Hz. ISO 16283-1 utilizes spatial averaging to determine transmission loss in the 50, 60, and 80 Hz bands. Conceivably one could measure down to 31Hz using these methods, and report the results with the understanding that this is specific to the particular measurement location; however, these test methods utilize white or pink noise as a noise

[1] dwoolworth@rwaconsultants.net

source. The test loudspeaker's ability to run continuous broadband noise at high sound levels is limited, and at high sound levels can burn up loudspeakers, especially trying to reproduce low frequency broadband noise. As seen in Figures 1 and 2, low frequency is our main concern in regard to clubs. So a test signal should be considered that mimics the part of the sound source that is the main complaint, that is primarily pulsing low frequency.

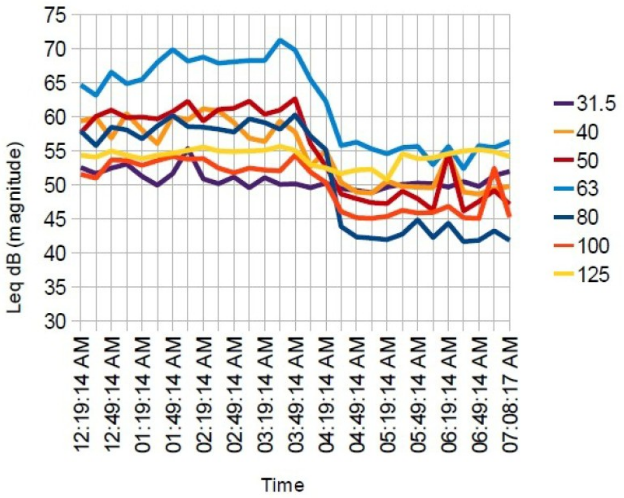

Figure 1: Third octave band measurements of Leq in a bedroom on 5th floor of condominium above an open stairwell with club on 1st floor, Note the drop in level of 15dB when the club closes at 4:00am.

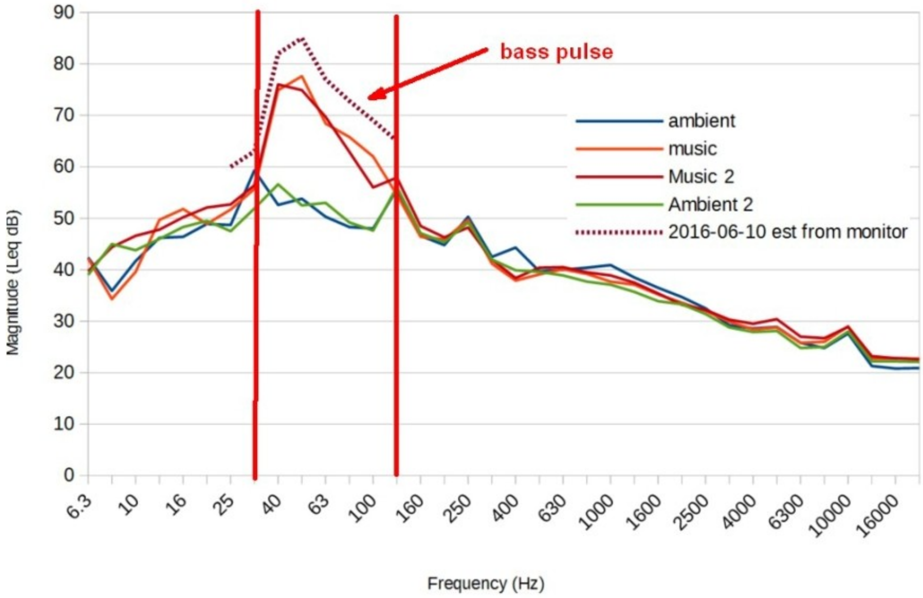

Figure 2: Outdoor measurements 29m (95ft) from a club in an apartment complex 12:00am versus ambient conditions.

2.2 Proposed Test Signal

Bass drops and the actual music played in the venue are useful sources that contain low frequency pulse information; live music will have large variations between acts and requires some additional thought to ensure the worst case is tested (see 2.4 Sound Level of the Test Source). The proposed test signal is a bass drop (or multiple types of drops).

2.3 What is a Bass Drop?

A bass drop is a bass drum type sound sample used in music for impact, or sometimes as a drum sound. It is sometimes referred to as "808" in reference to the bass drum sound of an early drum machine, the Roland TR-808, created by Ikutaro Kakehashi in 1980. This was initially used by the Japanese electronic music group Yellow Magic Orchestra, and was considered more of a toy, but drum machines began to drive new forms of music such as hip hop, and eventually the bass drop continued to evolve and be adapted for pop music, heavy metal, rap/urban music, and electronic dance music (EDM). (5)

The bass drops studied for this paper had a duration from ~200 msec to several seconds. In general, the sound consists of a band of low frequencies that drops pitch over time. For example, the drop in Figure 3 (left) starts out roughly in the band of 63Hz to 200Hz and drops to 31Hz to 80Hz in 0.2 seconds; with this frequency and level drop in the main band, higher frequency information will drop off in level as well. Bass drops are further manipulated by their composers using various electronic effects; harmonics are added to ensure good reproduction in sound systems with low frequency limitations.

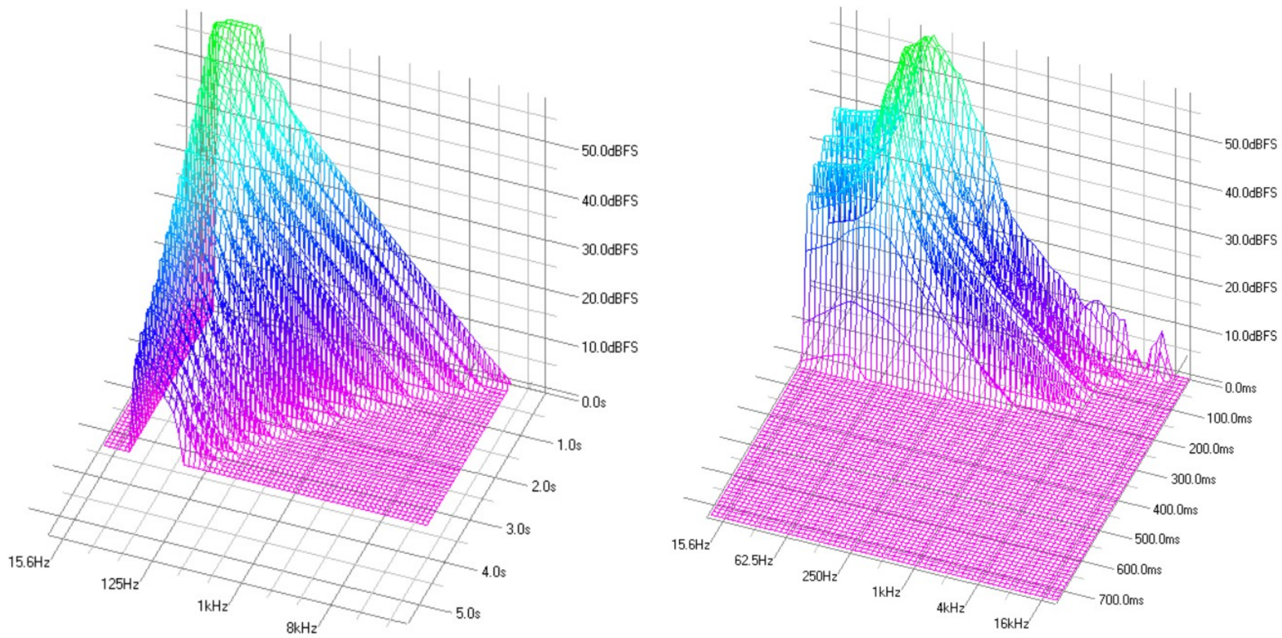

Figure 3: Waterfall analysis of two bass drops. Left, a well ordered oscillating 3 second drop; Right, a 0.2 second drop with some electronic effects. In both cases, the signal shifts to lower frequency over time.

2.4 Sound Level of the Test Source

The sound level of the test source is important and can be approached in several ways: (a) if we are trying to determine the upper level to limit the sound source, the level can be varied until a receiver criteria is met (b) if we are trying to evaluate the sound isolation between a source and a receiver, it is good practice to use low frequency sound levels that you have measured in similar venues. It is important to note that when field testing is performed, the sound levels that match typical levels can seem louder than normal, as you are going from ambient conditions to high sound levels, without the aid of tympanic reflex and other acclimation. It is not unusual for the owner or manager of a source venue to claim that they are never as loud as the test. The best point of reference for the highest sound levels for clubs will be the end of the night or the end of shows; the sound level is typically the highest then (See Figure 1). Live music venues requires that a sampling of acts is performed, as there can be large variations in the musicians' and engineers' low frequency sound levels.

Bass drop frequency content, frequency shift and sound level together will typically excite most lightweight surfaces in the room into vibration, actuating structureborne noise. Thresholds for airborne induced vibration of windows, walls, and floors with two field measurement samples are shown in Figure 4 for reference. It is important to keep in mind this airborne sound to structureborne sound can become the major issue for sound transmission.

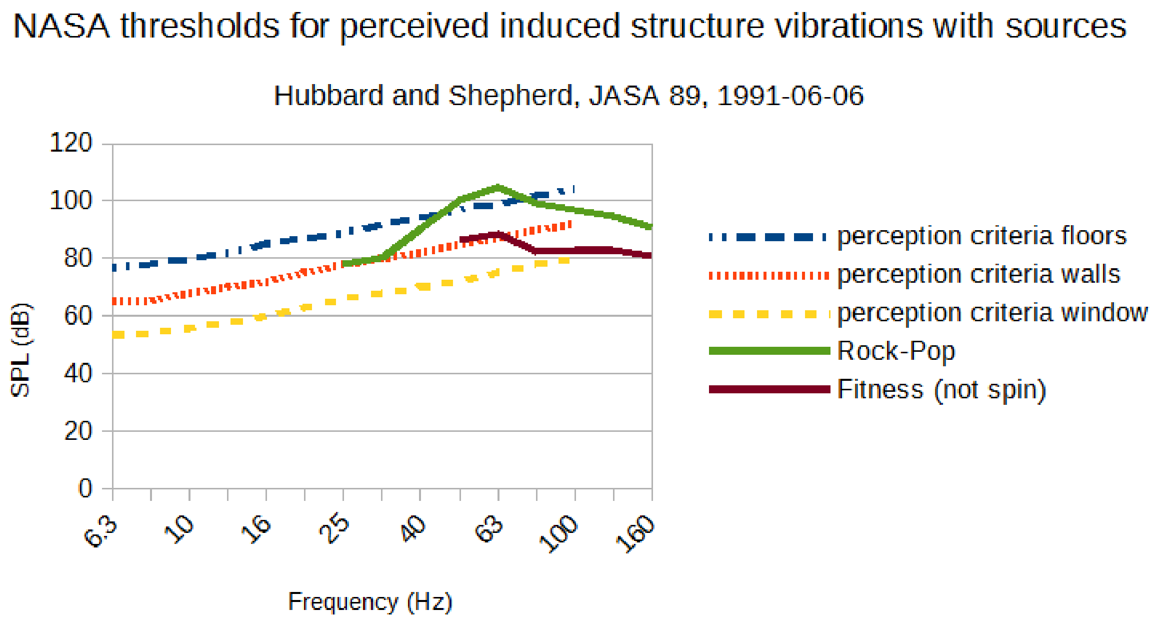

Figure 4: NASA thresholds of airborne sound levels producing perceived induced structural vibrations. Rock-pop curve extracted from Larsen(6) and author's field data, fitness is typical ambient conditions for a fitness facility. Note that "spin" (in-place bicycle class) can exceed the fitness level significantly (up to 10dB). Both typical field conditions can induce structureborne sound.

2.5 Sound Source and Testing

If a "house" sound system exists, it is the ideal source as it has the appropriate capacity and in-situ conditions of structural connectivity. In the case where no sound system is in place, or it is a live music venue, it is appropriate to bring a subwoofer that can reproduce down to ~30Hz, or whatever the planned system low frequency roll off is designed for. The stage should be checked separately in live music venues to simulate bass, synthesizer, or DJ setups, as the stage may have different structural connectivity than the house sound system. Regardless of the sound source, it is a good idea to bring isolation pads for subwoofers to examine any improvements by isolation, or to verify if structureborne sound is the main issue.

The test can utilize sound level meters or microphones in both the source and receiver positions (best), however it may be sufficient or necessary to sample some number of bass drops at the source and then again at the receiver under stable or low noise ambient conditions. Vibration monitoring is highly recommended. The interval, duration, and style of the bass drop (in some cases bass drum sample) can be set up to mimic an expected range of tempos if exposure is being considered; for instance, exercise music typically ranges from 115 to 160 beats per minute.

2.6 Using the Results

The data from testing for low frequency sound and vibration transfer using bass drops is especially useful in troubleshooting sound and vibration paths, determining required in-situ noise reduction of a construction, informing noise control measures, and determining limits for low frequency output of sound systems.

3. ON EVALUATION OF RECEIVER THRESHOLDS

3.1 Threshold Limits for Receivers

The discussion for receiver low frequency thresholds is ongoing; a recent summary of methods can be found in ICA 2016 proceedings (Caniato, et.al) (7), which includes Roberts (8) recommendation for 5dB penalty for an impulsive source (bass beat), and Jakobsen's method (9) that includes vibration monitoring (structureborne sound). This summary builds on earlier work from Leventhal (10). DIN 45680 Measurement and assessment of low-frequency noise immissions in the neighborhood (11) also recommends nighttime limits for sound and vibration. In some cases testing needs to be performed during the day, so it is important to take in to consideration background noise and penalties for nighttime ambient conditions. Determination of receiver metrics and refinement of methods for testing is left to the reader; ultimately it is important to measure both sound and vibration due to the potential for direct transfer of vibration and airborne to structureborne sound in addition to airborne sound.

4. SUMMARY

The "808" bass drop is an element of popular music that should be considered as a repeatable test signal added to standard field sound isolation testing to examine each unique field condition for music and entertainment that includes low frequency content. The value of the bass drop is that it defines "worst case" for sound levels and band-density in the low frequency region of music sources, making it useful in establishing limits for sound systems or defining isolation needed to meet threshold limits. The bass drop is particularly effective in generating airborne to structureborne sound, where white and pink noise test signals may not due to demands of continuous broadband sound on the loudspeaker.

Since the bass drop is an evolving art, it is difficult to define a standard drop sound, and the consultant needs to be vigilant of the "state of the art" in music production to determine a reasonable test signal(s). It is also critical for those involved in testing to identify any new elements in popular music that can create annoyance with unintended listeners and ensure that they include similar signals in field testing regimen. Ultimately the test signals should reflect the content and sound levels of a typical source or potential source.

5. FUTURE WORK

Three areas are of interest for future work; (a) sound quality (i.e. sharpness, roughness) of various bass drops and the potential for annoyance, (b) the creation of a library of genre or venue based music samples for field testing, and (c) development of indoor to outdoor sound transmission measurement method that addresses low frequencies of interest.

REFERENCES

1. Woolworth, David, "New Orleans Sound Ordinance and Soundscape; Evaluations and Recommendations," City Council Resources, City of New Orleans, August 5, 2013.
2. Hasnain, Zainab, "How the Roland TR-808 revolutionized music" The Verge, April 3. 2017, https://www.theverge.com/2017/4/3/15162488/roland-tr-808-music-drum-machine-revolutionized-music.
3. ISO 16283-1:2014 Field measurement of sound insulation in buildings and of building elements Part 1: Airborne sound insulation.
4. ASTM E336-19 Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings.
5. "Roland TR-808" Wikipedia, https://en.wikipedia.org/wiki/Roland_TR-808.
6. Adelman-Larsen, Neils Werner, "Rock and Pop Venues: Acoustic and Architectural Design", Springer, New York, 2014.
7. Caniato, Bettarelllo, Fausti, et al. "Low frequency noise and disturbance assessment methods: A brief literature overview and a new proposal," POMA, 22nd International Congress on Acoustics, Buenos Aires, Argentina, September 2016.
8. Roberts. C., "Ecoaccess guideline for assessment of low frequency noise," in Proceedings of

ACOUSTICS 2004, Gold Coast, Australia, November 2004.
9. Jakobsen, J. (2001): Danish guidlines on environmental low frequency noise, infrasound and vibration. Jnl Low Freq Noise Vibn & Active Control 20, 141-148.
10. Leventhall H G. Low frequency noise and annoyance. Noise Health [serial online] 2004 [cited 2019 Jun 9];6:59-72. Available from: http://www.noiseandhealth.org/text.asp?2004/6/23/59/31663 .
11. DIN 45680 – Measurement and evaluation of low-frequency noise immissions in the neightbourhood, 1997.

1. Beranek LL. Criteria for noise and vibration in buildings and communities. In: Beranek LL, Ver IL, editors. Noise and Vibration Control Engineering - Principles and Applications. 2nd ed. New York, USA: Wiley; 2006. p. 887-909.

7. Caniato, Bettarelllo, Fausti, et al. “Low frequency noise and disturbance assessment methods: A brief literature overview and a new proposal,” POMA, 22nd International Congress on Acoustics, Buenos Aires, Argentina, September 2016.
8. Roberts. C., “Ecoaccess guideline for assessment of low frequency noise,” in Proceedings of ACOUSTICS 2004, Gold Coast, Australia, November 2004.
9. Jakobsen, J. (2001): Danish guidlines on environmental low frequency noise, infrasound and vibration. Jnl Low Freq Noise Vibn & Active Control 20, 141-148.
10. Leventhall H G. Low frequency noise and annoyance. Noise Health [serial online] 2004 [cited 2019 Jun 9];6:59-72. Available from: http://www.noiseandhealth.org/text.asp?2004/6/23/59/31663 .
11. DIN 45680 – Measurement and evaluation of low-frequency noise immissions in the neightbourhood, 1997.