# LOCATION OF HORN SPEAKERS IN A REVERBERATION ROOM

**Ramani Ramakrishnan**
Department of Architectural Science, Ryerson University, Toronto, ON, Canada rramakri@ryerson.ca

## 1. INTRODUCTION

Considerable theoretical research has been conducted in understanding the design constraints as well as on the locations of horn speakers in reverberation rooms[1]. Many of the research methods applied simple sinusoidal source functions (tones) to evaluate the design criteria of horn speakers[1,2]. The understanding of the behaviour of horn speakers, when band limited random noise signatures such as pink noise and white noise are used as input sources, is still not clear. A hyperbolic horn with cut off frequency of 70 Hz was used in a medium sized reverberation room to study the horn behaviour. Some of the basic questions to be studied were the influence of horn location on the cut-off frequency, as well as the influence of the horn location on the diffuse sound field in the reverberation room. In addition, the influence of the input sound source on the room sound levels was also studied. Preliminary results of the experiment are presented in this paper.

## 2. BACKGROUND

The location of a source in a room is very much dependant on the expected sound field. Typical effects of locating the source in corners were highlighted in Bell[2] and Beranek[4]. The diffused sound in a reverberation room is supposed to reduce by the factors based on source's location in the room. Standard textbooks show that the 'Q' factors are 1, 2, 4, and 8 for the centre, single corner, double corner, and triple corner location of the source respectively. In addition, if horn (exponential, conical or hyperbolic) speakers were used in a reverberation room as the main source, the operating frequencies can be modified based on the location of the horn. It is hypothesized for example, that if the horn is located in a triple corner, the cut off frequency can be reduced or the mouth size can be reduced. The current experiment was undertaken to test the above hypothesis.

## 3. THE REVERBERATION CHAMBER

The reverberation chamber at Concordia University was used to conduct the experiment.

### 3.1 Chamber details

The reverberation chamber is located in the engineering building of Concordia University, Montreal and is used by the Building, Civil and Environmental Engineering Department (BCEE). The characteristics of the chamber are: Length, L = 6.13 m; Width = 6.96 m; Height = 3.56 m; Chamber Volume = 152.3 cu.m.

The $RT_{60}$ varied between 0.8 sec to 3 sec. across the frequency band. The two cut-off frequencies of the room were estimated to be 188 Hz and 64 Hz[5,6,7]. The results of Reference 5 showed that for a broadband signal, the chamber had good spatial uniformity from 63 Hz (1/3 octave band) and above.

### 3.2 Horn Speaker details

A hyperbolic horn speaker was used for the tests. The horn in a triple corner is shown in Figure 1. The horn details are: the horn length is 92.1"; the throat area is 2.1 sq. in; the mouth area 397.5 sq. in.; band width is from 68 to 219 Hz; and the horn volume is 3.7 cu. ft.

**Figure 1. The Hyperbolic horn at a triple corner (The microphone boom is in the background).**

The horn was connected to an AURA NS3-193-8A speaker with frequency response from 50 Hz to 7000 Hz (±3 dB).

## 4. THE EXPEERIMENT

The experiment basically consisted of driving the speaker-horn combination with single sinusoids or band filleted random noise. The diffused sound field was measured by using a microphone boom at two different heights. The equivalent sound level over a 30 second traverse of the boom was calculated. The measurements were conducted for three locations of the horn – the horn speaker in triple corner (as shown in Figure 1); the horn speaker was moved diagonally by 2 feet; and the horn speaker was moved diagonally by 4 feet. The last location would represent a double corner somewhat. Different combinations of the horn speaker locations were also tested. The results for the above triple corner only are presented in this paper. As mentioned earlier, the operating frequency of the hyperbolic horn is from 68 Hz to 219 Hz. The above band width was determined by the manufacturer from the design of hyperbolic horn. The length and the mouth area were

evaluated after fixing the cut-off frequency and the upper limit frequency of the horn design.

## 5. RESULTS AND DISCUSSION

The room SPLs for various conditions are shown in Figures 2, 3 and 4 below.

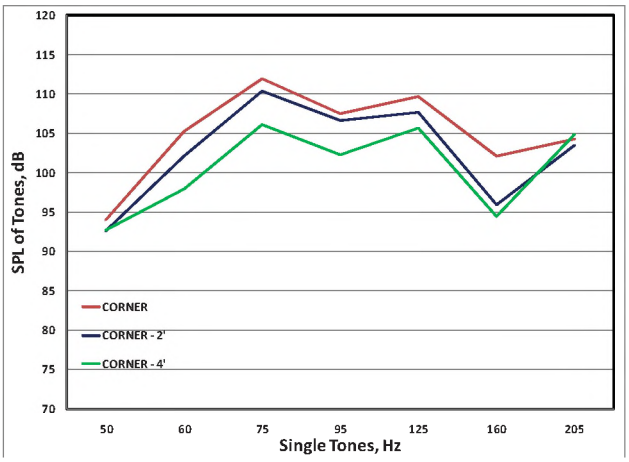


**Figure 2. Room SPL variation – single tones.**

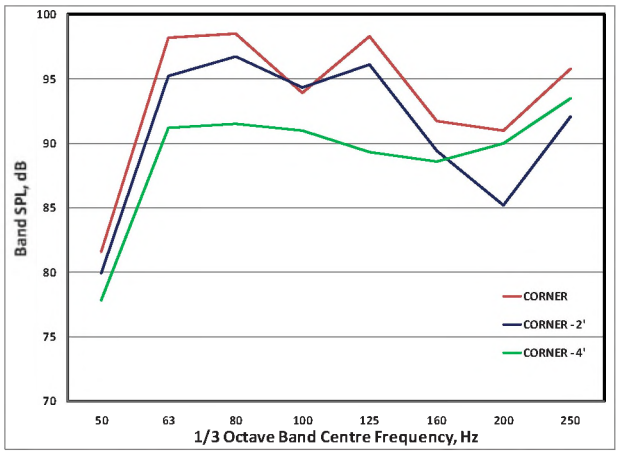


**Figure 3. Room SPL variation – Band filtered noise.**

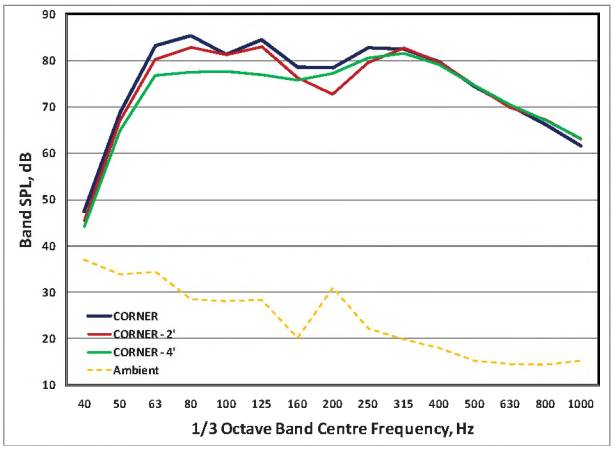


**Figure 4. Room SPL variation – pink noise (40 to 10kHz).**

The SPL variations in the room for sinusoidal sources are shown in Figure 2. The room SPLs between 60 Hz and 160 Hz are seen to follow the typical 'Q' factor variation of 3 to 4 dB differences. The behaviour below 60 Hz and above 200 Hz, is seen to be indifferent to the speaker location. Even though a strong signal was generated at 50 Hz, the triple corner effect is non-existent. The results for band-filtered random noise are shown in Figure 3 and much broader pink noise results are shown in Figure 4. The speaker location's effect is unpredictable for the band-filtered random noise within the operating range of the horn. The speaker location had absolutely no effect when the broader pink noise was generated. No consistent 'Q' factor effect was evident in the results of Figures 3 and 4.

## 6. CONCLUSIONS

The effect of the location of a horn speaker in a reverberation room was tested. The effect was evident in the sinusoidal input signals. When random noise and/or broad band signals were used as input, the preliminary results show that the speakers location had no impact on the diffused sound levels of the reverberation chamber.


### ACKNOWLEDGMENTS

The reverberation room tests were conducted at Concordia University, Montreal. The kind assistance provided by the BCEE (Building, Civil and Environmental Engineering) department is duly acknowledged.


## REFERENCES


1. Leo L. Beranek, *Acoustics* American Institute of Physics (1986).
2. John Murray, "The Quadratic-Throat Waveguide," Peavey Electronics Corporation (2000).
3. Lewis H. Bell, *Industrial Noise Control* Marcel Dekker Inc. New York (1982).
4. Leo L. Beranek, *Noise and Vibration Control* Institute of Noise Control Engineering. (1988).
5. R. Ramakrishnan and A. Grewal, "Reverberation Rooms and Spatial Uniformity." Proceedings of the Acoustics Week in Canada 2008, Vancouver. *Canadian Acoustics*, Vol. 36 (#3) (2008).
6. M. R. Schroeder, "Frequency-Correlation Functions of Frequency Responses in Rooms," J. Acoust. Soc. Am. Vol.34, pp. 1819, 1962. Also J. Acoust. Soc. Am. Vol.46, pp. 277-283, 1969.
7. F. Slingerland, G.M. Elfstorm and W.E. Grün, "Performance and Operational Capabilities of the Large European Acoustic Facility (LEAF)," Proceedings of the International Symposium on Environmental Testing of Space Programmes – (ESA SP-304, September 1990).