Advancing the Technology and Practice of Noise Control Engineering

An Investigation of HVAC Directivity: Theory versus Reality

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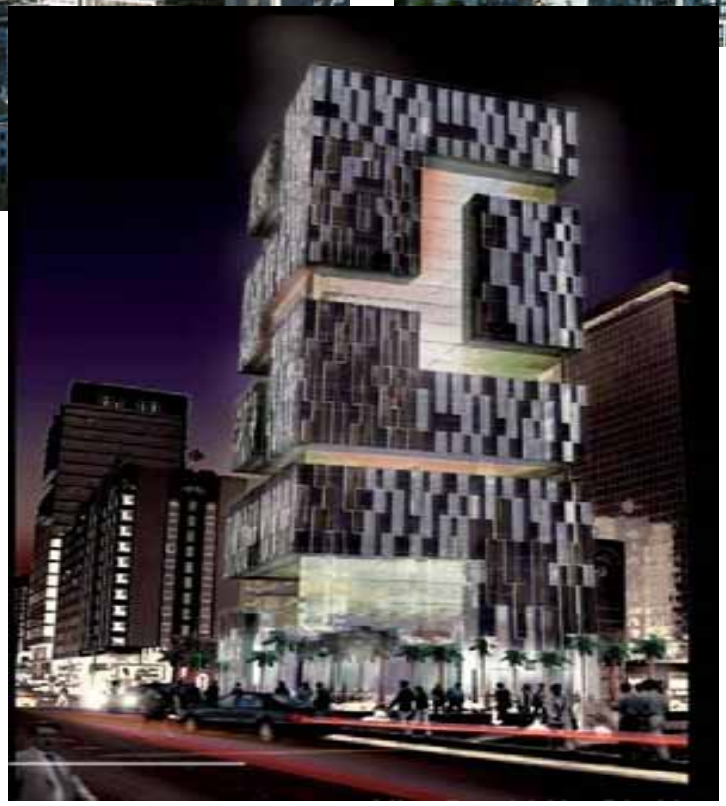
1. Introduction

Urban Development Trends…

- Sprawl: Compartmentalized land use, high reliance on cars, incompatible adjacent land uses
- Densification: Planned density to support urban re-development, enhanced public transport, sustainable community

2. Background

More than ever we are building up…



HVAC + Penthouse Suite = Nuisance Noise Exposure + Complaints

- Mechanical and comfort equipment is roof mounted
- Continuous mechanical noise peaks in summer
- Living room and bedroom windows ultra-sensitive

What do acoustic consultants do anyways?

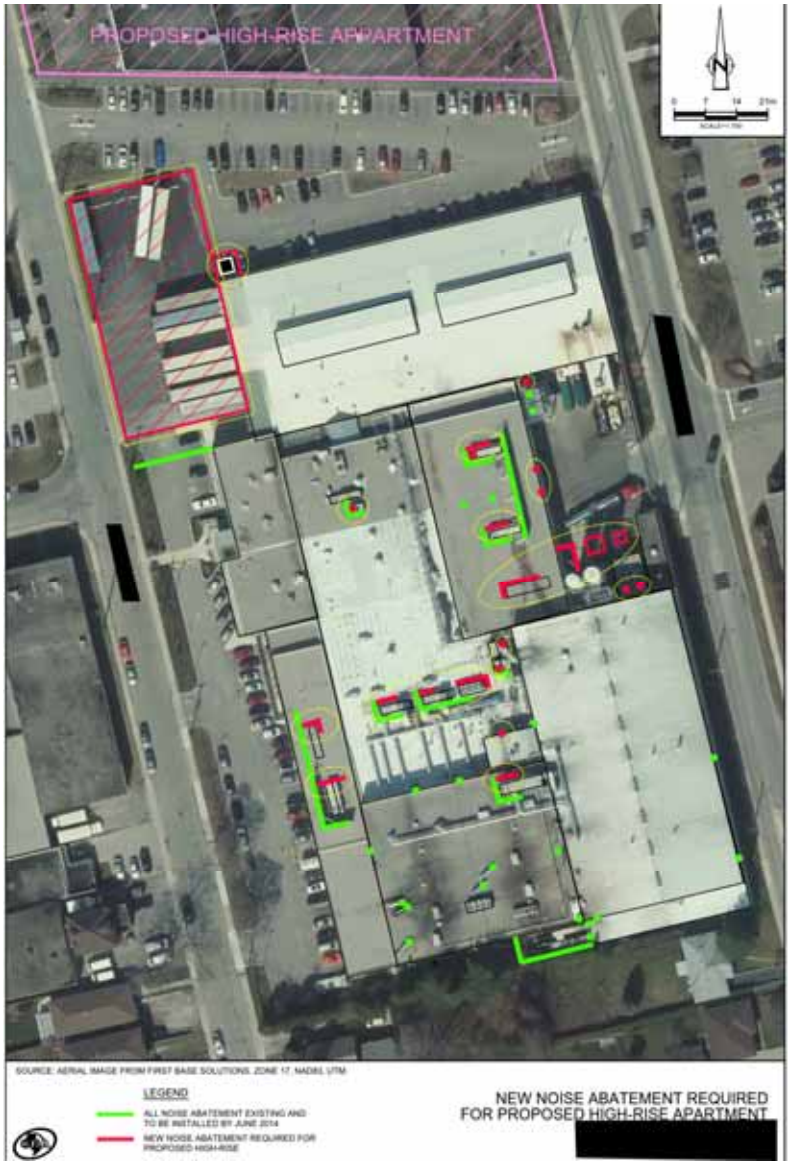
Before = industrial land use

After = mixed land use

Assessment of Noise Impacts for Mixed Land Use

- New sensitive use means new LOS
- Potential new complainants
- New control requirements and costs
- High rise = “High” risks

Approved development
= non-compliance overnight



An Investigation of HVAC Directivity: Theory versus Reality

- Most practical to evaluate noise control requirements at design stage
- Point-source analysis does not fit all
- Field study to evaluate the source noise and directivity character of industrial HVAC unit
- Actual source-defined directivity compared against a published technical resource

Methodology I – Rooftop Source Characteristics

- 3 cooling fans at the top of the unit were predominant
- Secondary compressor motor noise at the base of the unit (> 10 dBA lower sound power level)

Methodology I – Survey Measurement Results

- Preliminary, informal ISO 3744-2 survey determined PWL = 95 dBA (100% load)
- Directivity measurements at 45 degrees versus 90 degrees perpendicular to the fan array
- Measured 2 dBA total sound pressure level difference (45 vs 90 degrees)

Methodology I – Detailed Measurement Results

- Extensive surface area SPL measurement procedure
- PWL = 92 dBA (100% load)
- SPL re-measured for select microphone positions, 1 m from the top edge of the HVAC unit
- Triplicate, positions 0, 22, 52, 75, 112, 157 and 180 degrees to determine the directivity for the unit

Methodology II – Field Measurements Example

Directivity Correction Comparison – Results and Discussion

- 3 fan unit, each approximately 0.6 m diameter (2 feet)
- Equivalent total fan surface area rounded to 1 m^2 or 10 square feet
- Measured directivity corrections compared against the Design Guide for Shipboard Airborne Noise Control corrections

Results and Discussion II

Typical HVAC

Angle for Receiver	CRA HVAC Directivity Corrections (dB)								
Location	31.5	63	125	250	500	1000	2000	4000	8000
0°-22°	0	-1	2	1	1	1	2	1	0
23°-52°	0	-2	-1	-1	0	0	0	0	-1
53°-75°	0	-3	-4	-3	-1	-2	-3	-2	-3
76°-112°	0	-3	-5	-5	-3	-2	-5	-5	-4
113°-157°	0	-4	-8	-4	-6	-7	-8	-10	-12
158°-180°	0	-3	-6	-7	-6	-8	-9	-12	-14

Angle for Receiver	Naval Stack Directivity Corrections (dB) - Area of Stack Opening - 8 -32ft^2								
Location	31.5	63	125	250	500	1000	2000	4000	8000
0°-22°	0	1	3	4	5	5	5	5	5
23°-52°	0	0	0	0	1	3	5	5	5
53°-75°	0	-1	-5	-9	-10	-11	-12	-13	-14
76°-112°	0	0	-1	-5	-9	-10	-11	-12	-13
113°-157°	0	-1	-5	-9	-12	-14	-16	-18	-20
158°-180°	0	-1	-5	-9	-12	-14	-16	-18	-20

Angle for Receiver	Delta between CRA Measured Directivity and Naval Stack Corrections								
Location	31.5	63	125	250	500	1000	2000	4000	8000
0°-22°	0	2	1	3	4	4	3	4	5
23°-52°	0	2	1	1	1	3	5	5	6
53°-75°	0	2	1	6	9	9	9	11	11
76°-112°	0	3	4	0	6	8	6	7	9
113°-157°	0	3	3	5	6	7	8	8	8
158°-180°	0	2	1	2	6	6	7	6	6

Results and Discussion III

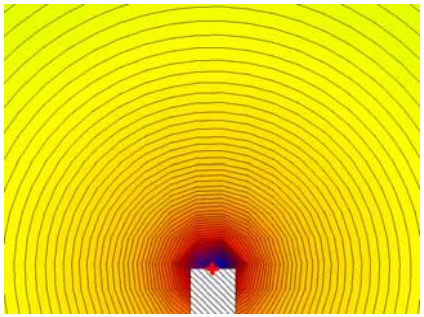
- Yellow highlights for matching octave bands that differ by 3 or more
- Significant number of discrepancies, evidently different

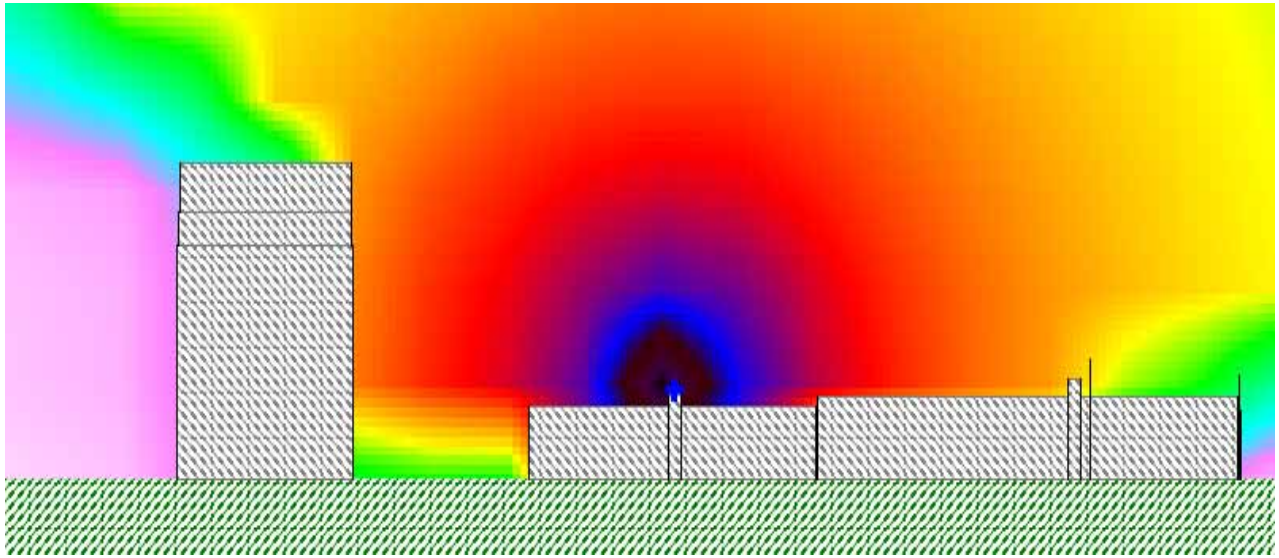
Angle for Receiver	Delta between CRA Measured Directivity and Naval Stack Corrections								
Location	31.5	63	125	250	500	1000	2000	4000	8000
0°-22°	0	2	1	3	4	4	3	4	5
23°-52°	0	2	1	1	1	3	5	5	6
53°-75°	0	2	1	6	9	9	9	11	11
76°-112°	0	3	4	0	6	8	6	7	9
113°-157°	0	3	3	5	6	7	8	8	8
158°-180°	0	2	1	2	6	6	7	6	6

Results and Discussion V

Figure 1 illustrates omnidirectional noise propagation (no directivity corrections)

- Not realistic, over-predicts in most cases
- Over-estimates the effectiveness of a barrier wall

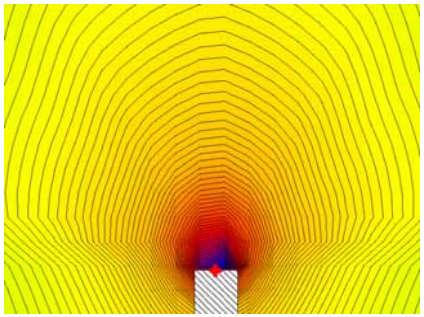


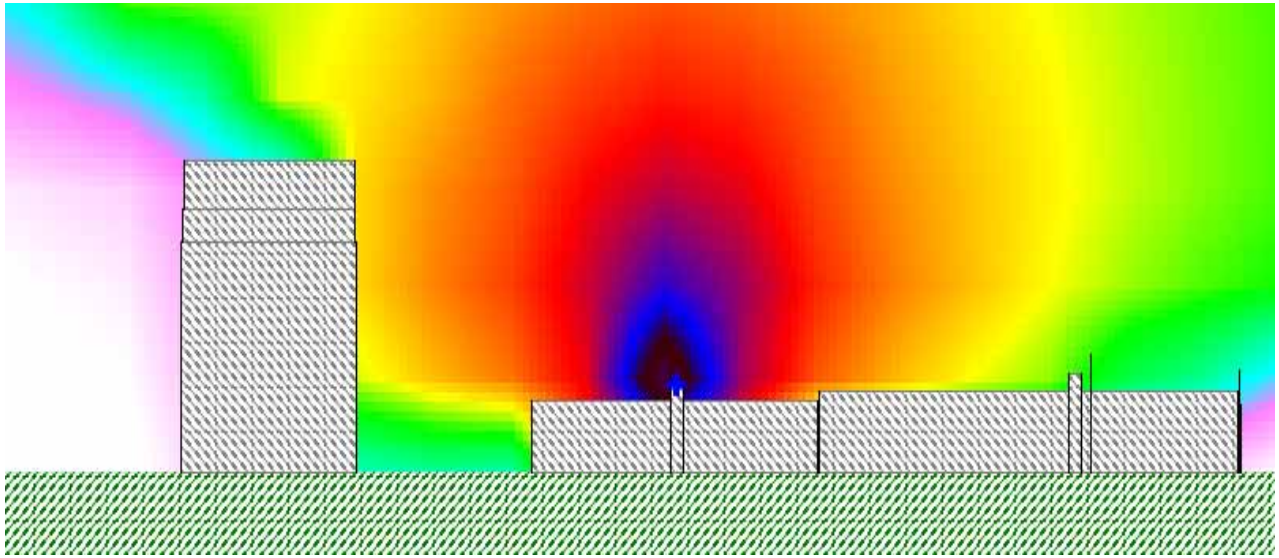


Results and Discussion VI

Figure 2 illustrates the measured directivity propagation

- Noise “profile” constrained to shape of the unit
- Amplified candle shape at 0 to 22 degrees

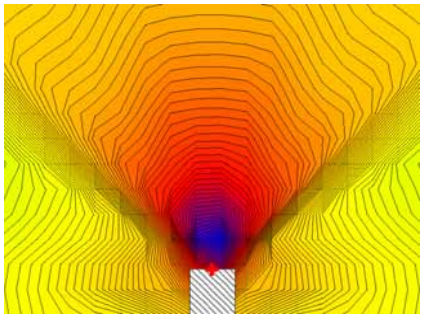


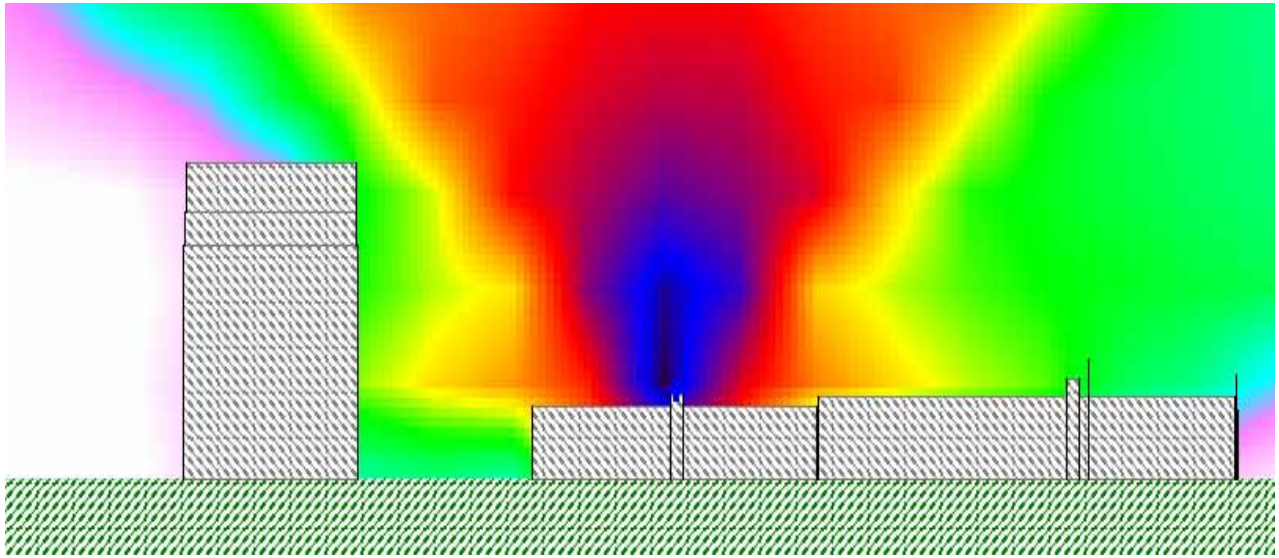


Results and Discussion VII

Figure 3 illustrates the Naval Stack directivity propagation

- Pronounced V-shape amplified from 0 to 52 degrees
- Under-prediction level or lower LOS (53 to 180 degrees)
- Barrier wall ability to mitigate elevated LOS?





Theory versus Reality 2.0: 2014 Field Tests

- Additional measurements in 2014 for a variety of single and two fan units
- Other SPL measurements at doubling distances from the entire unit for model analysis validation, up to 8 m away
- SPL modelled as PS for top fan(s) and the proposed directivity correction applied
- Real world at-source and at distance measurements compared well to the model results
- **Proposed HVAC directivity correction was a best fit to the measured field conditions for 7 new units tested!**

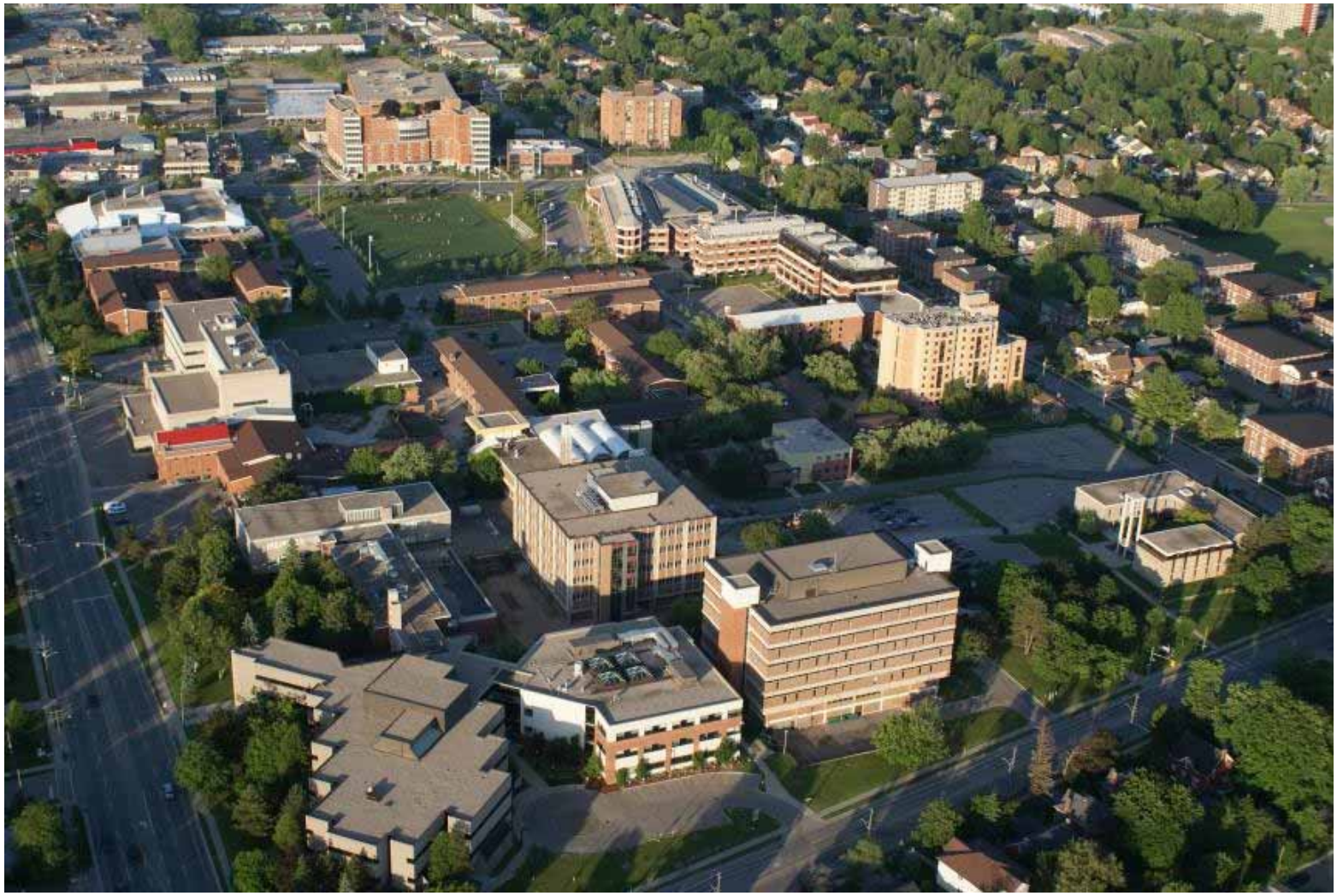
…so what?

- High rise development means more people view previously unseen rooftops
- Increase LOS noise impact exposure

Understanding the directivity character of any noise source is critical to:

a) accurately predict the receiver noise impact exposure
b) select the most suitable noise control
c) inform intelligent urban design

Intelligent Urban Regeneration can balance mixed land use interests!



Conclusions I

- Not all noise sources radiate sound uniformly in all directions
- Corrections to account for noise propagation that is amplified and constrained according to the directivity character of that source should be considered to inform off-site noise predictions and suitable control design
- This presentation has defined the directivity character of an HVAC unit based on field testing and compared it to published corrections from a technical resource

Conclusions II

- Actual versus published corrections were not similar
- Further research should be conducted in partnership with HVAC manufacturers to develop directivity corrections suitable to HVAC equipment
- Technical resource would be a tool for the use of acoustic consultants, developers and architects and for the benefit of accurate noise impact modeling and improved urban design

Questions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