Limitations of Environmental Noise Modeling

AWMA/OS Modeling Conference

October 22, 2013

HGC Engineering
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Presentation Outline

- Why Talk About Limitations?
- Why Do We Need to Model?
- Common Method for Environmental Modeling
- The ***Real*** Equation
- Simplification – Types of Acoustical Model
- Limitations
- Sources of Inaccuracy

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Why Talk About Limitations?

- There are a LOT of individuals conducting acoustic modeling who do not know the fundamentals
- ALL modeling is a garbage-in-garbage-out process. Without knowing fundamentals… => Garbage out
- Modern modeling software is so user-friendly, it can lull us into complacency (and the delusion that we know what we're doing)

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Rob's Three Key Rules of Modeling

1. The model is not reality
2. The model is not reality
3. The model is not reality

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Oh… and Two More Rules

4. Understand the simplifications of the modeling method

5. Verify/calibrate your results

Why Do We Need to Model?

- New facility – not yet built
- Proposed change to facility
- Contribution of individual sources (ranking)
- Identify sources requiring abatement
- Determine per-source abatement needed
- Design noise control measures
- Isolate sound of facility from interfering sound

Q: What is the common method used for Environmental Acoustical Modeling?

A: Ray Tracing

Q: Is sound a ray?

A: No, sound is a *wave*.

Q: So why do we (can we) model as a ray?

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The *Real* Equation

The wave equation (acoustic, not EM)

Derivation:

$$\frac{\delta \rho}{\delta t} + \rho_0 \cdot \nabla^{\rightarrow} \cdot v_{(x,y,z)} = 0$$

(1) Conservation of mass equation

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The *Real* Equation

The wave equation (acoustic, not EM)

Derivation:

$$\rho_0 \cdot \frac{\partial v_{(x,y,z)}}{\partial t} = -\nabla^{\rightarrow} p$$

(2) Momentum equation (Newton's 2nd Law)

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The *Real* Equation

The wave equation (acoustic, not EM)

Derivation:

$$p \approx c^2 \rho + P_0$$

(3) Ideal Gas Law (Linearized)

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The *Real* Equation

Do some calculus, make some substitutions,
Perform some regrouping, and…

$$\nabla^2 p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = 0$$

Tada!... the *wave equation*

A partial differential equation with four independent dimensions – 3 spatial and time

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The *Real* Equation

Special case – steady sound…

If,

$$p = Pe^{i\omega t}$$

Then,

$$\nabla^2 P + k^2 P = 0$$

Helmholtz Equation. *P* = pressure amplitude and *k* = wave number (*ω/c*)

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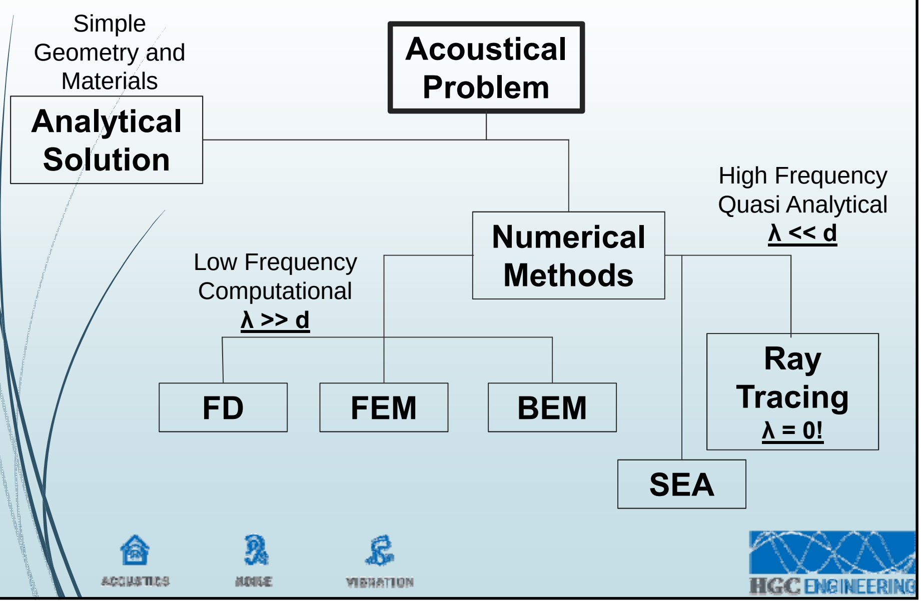
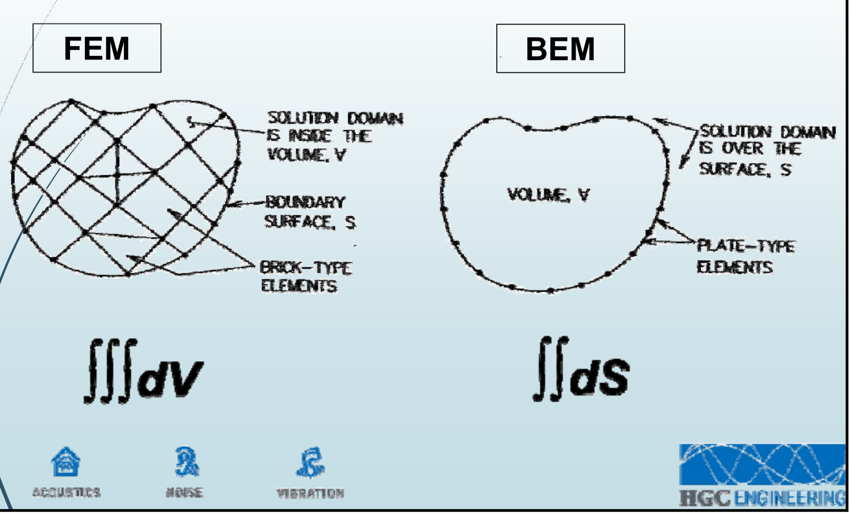
Simplifications – (Modeling)

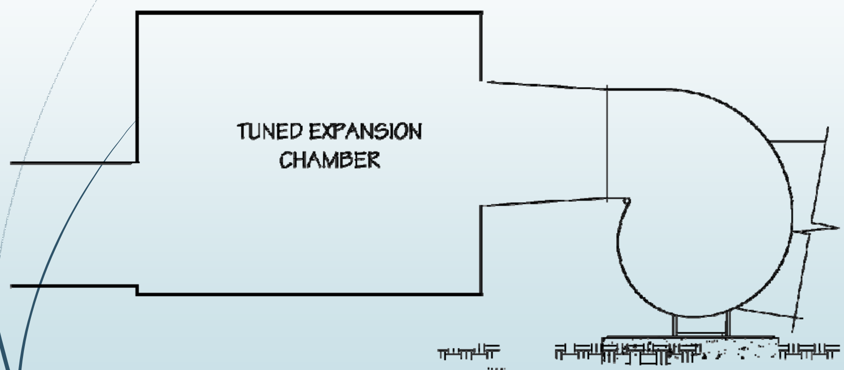


Aside: Compare Computational Methods



$\iiint dV$ $\iint dS$

Sample Boundary Element Model



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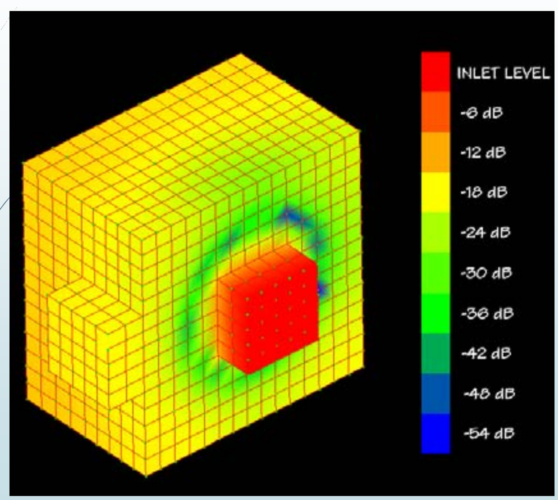
Sample Boundary Element Model



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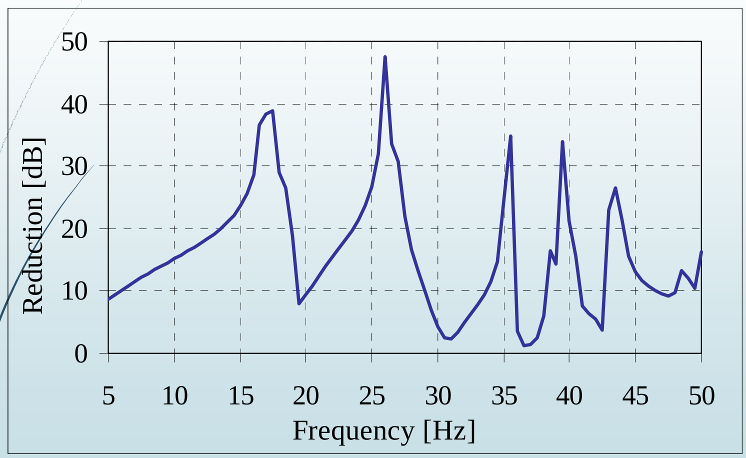
Sample Boundary Element Model



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Sample Boundary Element Model

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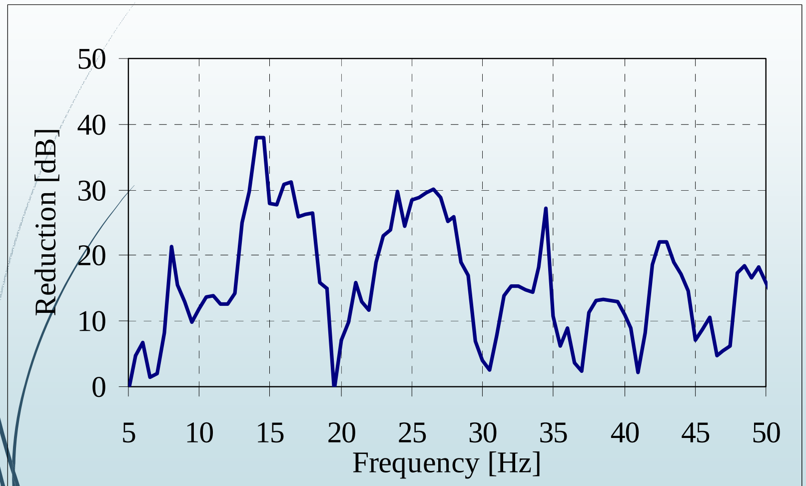
Sample Boundary Element Model



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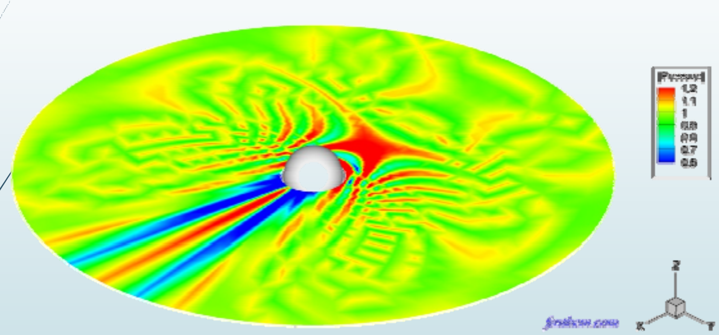
BEM Outdoors – Simple Geometry



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Environmental Acoustical Modelling

Ray Tracing

$\lambda = 0$!!

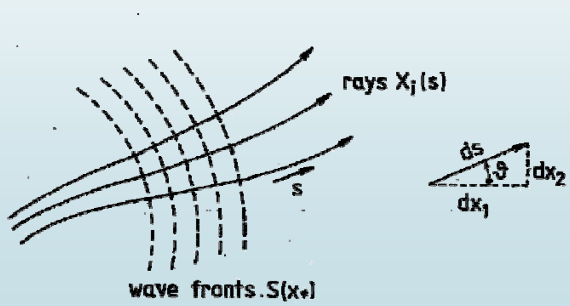
No wave effects!

Purely geometrical calculations

Environmental Acoustical Modelling

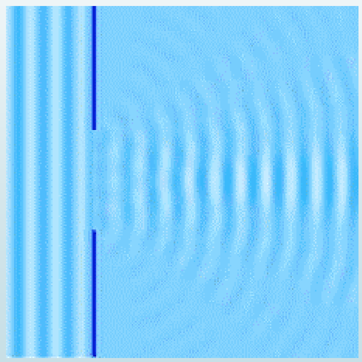
Ray Tracing

$$\frac{dX_i(s)}{ds} = \frac{1}{|\text{grad}\, S|}\frac{\partial S(x_j)}{\partial x_i}, \qquad i = 1, 2, 3$$



Environmental Acoustical Modelling

Ray tracing can’t truly calculate diffraction



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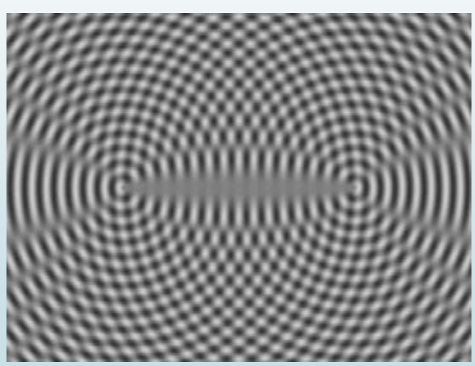
Environmental Acoustical Modelling

Ray tracing can’t calculate interference



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Environmental Acoustical Modelling

Instead, ray tracing models calculate the geometry (assuming rays) and approximate wave effects by superimposing simplified analytical approximations

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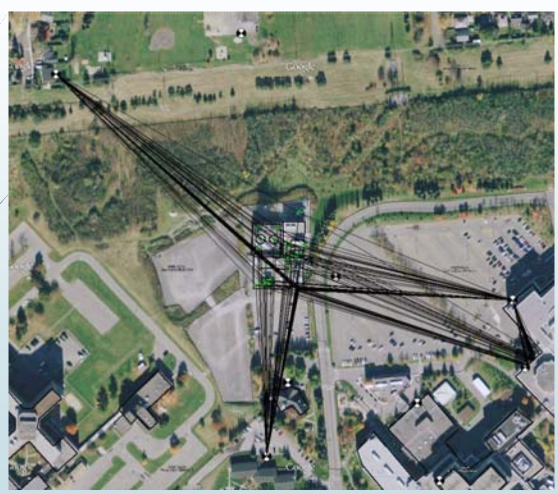

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Environmental Acoustical Modelling

ISO 9613-2

Lr = Lx - Adiv + K0 + Dc – Agnd

– Abar – Aatm – Afol – Ahous

– Cmet – Refl

Environmental Acoustical Modelling

- Adiv — Geometric divergence
- K0 — Solid angle correction
- Dc — Directivity coefficient
- Agnd — Ground absorption
- Abar — Barrier attenuation
- Aatm — Atmospheric absorption
- Afol — Foliage attenuation
- Ahous — Attenuation by scattered structures
- Cmet — Meteorological effects
- Refl — Reflections

(Red indicates a frequency dependent (wave) effect)

Environmental Acoustical Modelling

Limitations of Modeling Barriers

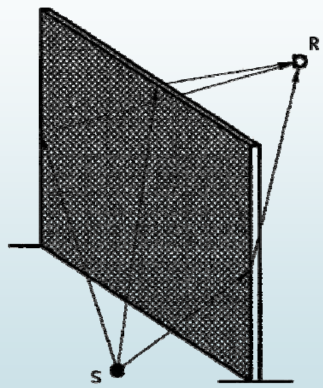

Figure 5 — Different sound propagation paths at a barrier

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Environmental Acoustical Modelling

Limitations of Modeling Barriers

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Environmental Acoustical Modelling

Limitation – Ignores (or crudely addresses) Interaction Among Attenuation Mechanisms

Example: Abar vs Agnd

For the purposes of this part of ISO 9613, the attenuation by a barrier, A_{bar}, shall be given by the insertion loss. Diffraction over the top edge and around a vertical edge of a barrier may both be important. (See figure 5.) For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by

$$A_{bar} = D_z - A_{gr} > 0 \quad \text{. . . (12)}$$

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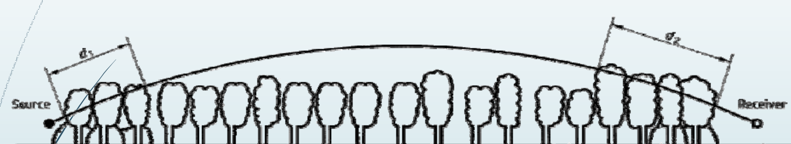
Environmental Acoustical Modelling

Limitation – Atmospheric Effects are Crudely Modeled (Circular Curve = Implies linear monotonic gradient)



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

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Environmental Acoustical Modelling

Summary of Simplifications/Limitations:

- Wave propagation is modeled as a ray
- Ray calculation is purely geometric
- Approximations for wave phenomena are (crudely) estimated and superimposed
- Wave phenomena (attenuation mechanisms) are (crudely) assumed to be independent when in fact they are interrelated

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Environmental Acoustical Modelling

Verify results! How?

- Calibrate model against mid-field or far-field measurement results

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Environmental Acoustical Modelling

Verify results! How?

Table A3
Acoustic Assessment Summary Table

Point of Reception ID	Point of Reception Description	Sound Level at Point of Reception[1] (L_{eq})	Verified by Acoustic Audit (Yes/No)	Performance Limit[2] (L_{eq})	Compliance with Performance Limit[3] (Yes/No)
POR1	House to North	46 dBA	Yes	54 dBA	Yes
POR2	House to East	48 dBA	Yes	52 dBA	Yes
POR3	Nursing Home to South	41 dBA	Yes	50 dBA	Yes
POR4	School to West	48 dBA	Yes	50 dBA	Yes

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Environmental Acoustical Modelling

Verify results! How?

- **Calibrate model against mid-field or far-field measurement results**
- **Use different methods to compare answers (e.g., manual calculation)**
- **Sensitivity analyses**
- **Engineering experience**

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End of Prepared Material!
Open for questions…

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