AN IMPROVED LOW FREQUENCY RADIATION MODEL FOR FINITE SOUND REFLECTORS

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Acoustics ’08 Paris
June 30, 2008
Reflector Panels/Canopies /Clouds
Simulation Methods

Boundary Element Method (BEM)
Sysnoise Rev 5.6

Geometric method
ODEON v9.0
BEM Validation
Simulation Geometry

- Square Reflector (1.2 m x 1.2 m)
- Receiver Plane (15 m x 15 m)
- Source
Research Questions

- What causes low frequency *discrepancy* between simulations?

- How can we modify geometric method to lessen this discrepancy?
Geometric Method Reflector Model (KFDA)
Monopole/Dipole Radiation

- Monopoles: \( \text{energy} \sim f^2 \rightarrow 6 \text{ dB / octave} \)

- Dipole: \( \text{energy} \sim f^4 \rightarrow 12 \text{ dB / octave} \)
  - Occurs at low frequencies for baffled piston (Beranek 1993) and for baffled loudspeakers (Olson 1957) when \( f < c/2l \)
Dipole Limit Frequency, $f_d$

- We observe that *reflector* radiates as a dipole below the dipole limit frequency, $f_d = c/2l$
- Does $f_d$ vary according to the same parameters as the geometric limit frequency, $f_g$?

\[
 f_g = \frac{c a^*}{2S \cos \theta}
\]

- Source/Receiver Distance
- Incidence Angle
- Reflector Area
$f_d$ : Variance with S/R Distance

$f_d$ does not depend on source and receiver distances.
$f_d$ : Variance with Incidence Angle

$f_d$ varies only slightly with incidence angle
$f_d : \text{ Variance with Reflector Size}$

$f_d$ varies inversely with dimension of square reflector.
Dipole Limit Frequency

• Of the three parameters tested, $f_d$ varies only with dimension of square reflector

\[ f_d = \frac{c}{2l} \]
Updated Reflector Model

-6 dB/octave

-12 dB/octave (proposed slope for $f < f_d$)

$f_{dipole}$

$f_{geometric}$

Frequency

Attenuation [dB]

6 dB/octave

12 dB/octave (proposed slope for $f < f_d$)
Applying Updated Reflector Model

- Idea 1: increase diffraction-based scattering coefficient in proportion with slope of radiation curve
Idea 1 does *not* correct low frequency discrepancy!
Applying Updated Reflector Model

- Idea 2: increase transparency coefficient in proportion with slope of radiation curve
Idea 2 does correct low frequency discrepancy!
Conclusions

- What causes low frequency discrepancy between geometric prediction and BEM prediction?
  - Dipole Limit Frequency, $f_d$
  - Geometric handling of diffraction (including above $f_d$)

- Can geometric method be modified to correct low frequency predictions?
  - Idea 1: Increase diffraction-based scattering
  - Idea 2: Increase transparency of finite panel
Further Work

- Classify behavior of $f_d$ when panel is non-square
- Classify behavior of $f_d$ for reflector arrays
Thank You

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• Work Supported by National Science Foundation

• Support for presentation of this paper has been provided through a grant from the Office of Naval Research (ONR)