Benchmark platforms on noise barriers

<u>Noise propagation from road traffic or railways</u>

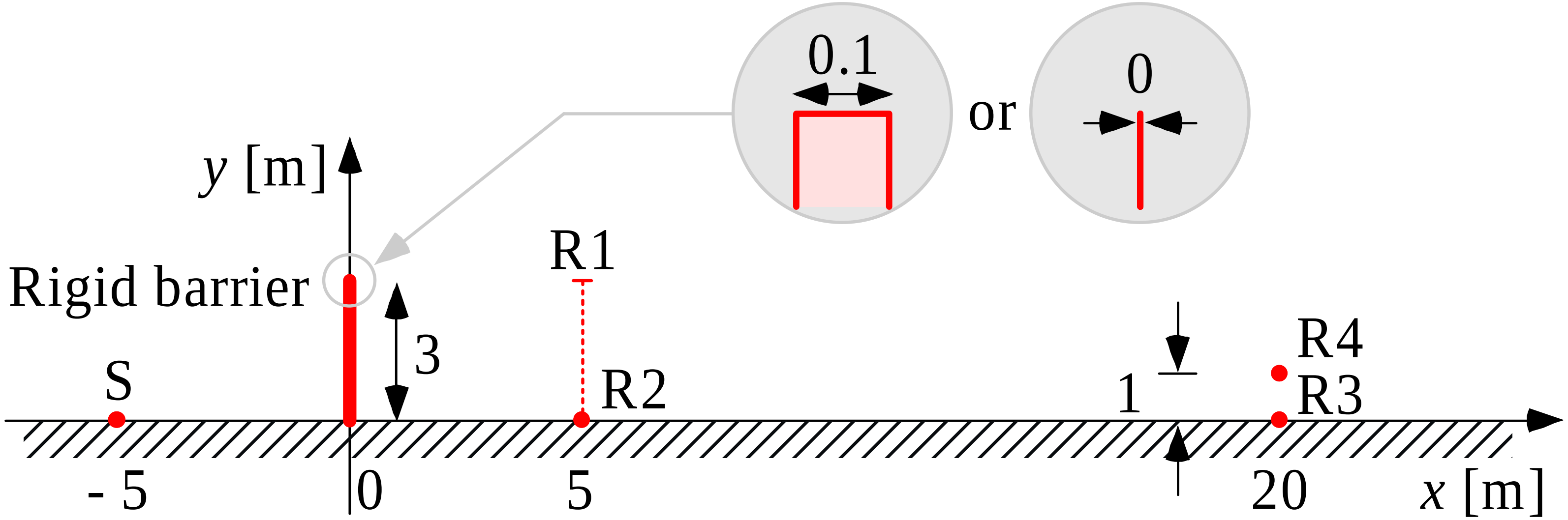
Traditional: energy-based prediction

Recently: wave-based numerical prediction

- “Edge-modified” barriers
- Complicated terrain

Fundamental of prediction — **Diffraction by noise barriers**

Simple barrier problem (A1-3F)



Insertion Loss (IL) = $SPL_{NoBarrier} - SPL_{WithBarrier}$

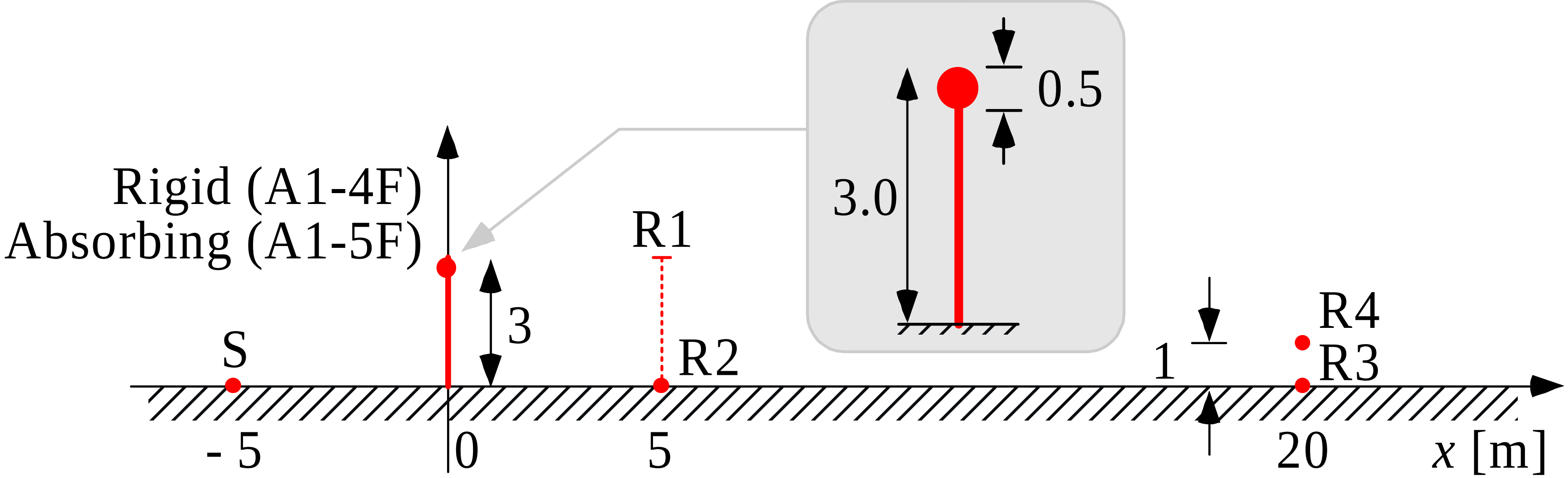
Task A: IL spatial distribution along R1

Task B: IL frequency characteristics on R2-R4

Intentions:

- Very simple so that various solutions are expected.
- Thickness effect 1: non-uniqueness arises in BEMs.
- Thickness effect 2: barrier efficiency increases.

Rounded-edge barrier problem (A1-4F & A1-5F)



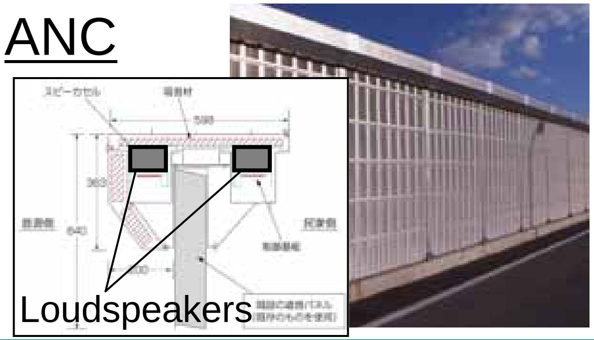
Intentions:

- Non-uniqueness shifts into lower frequency range.
- Non-uniqueness still remains even if absorbing (A1-5F).
- Application to design of “edge-modified” barriers.

Absorber

Interference

ANC

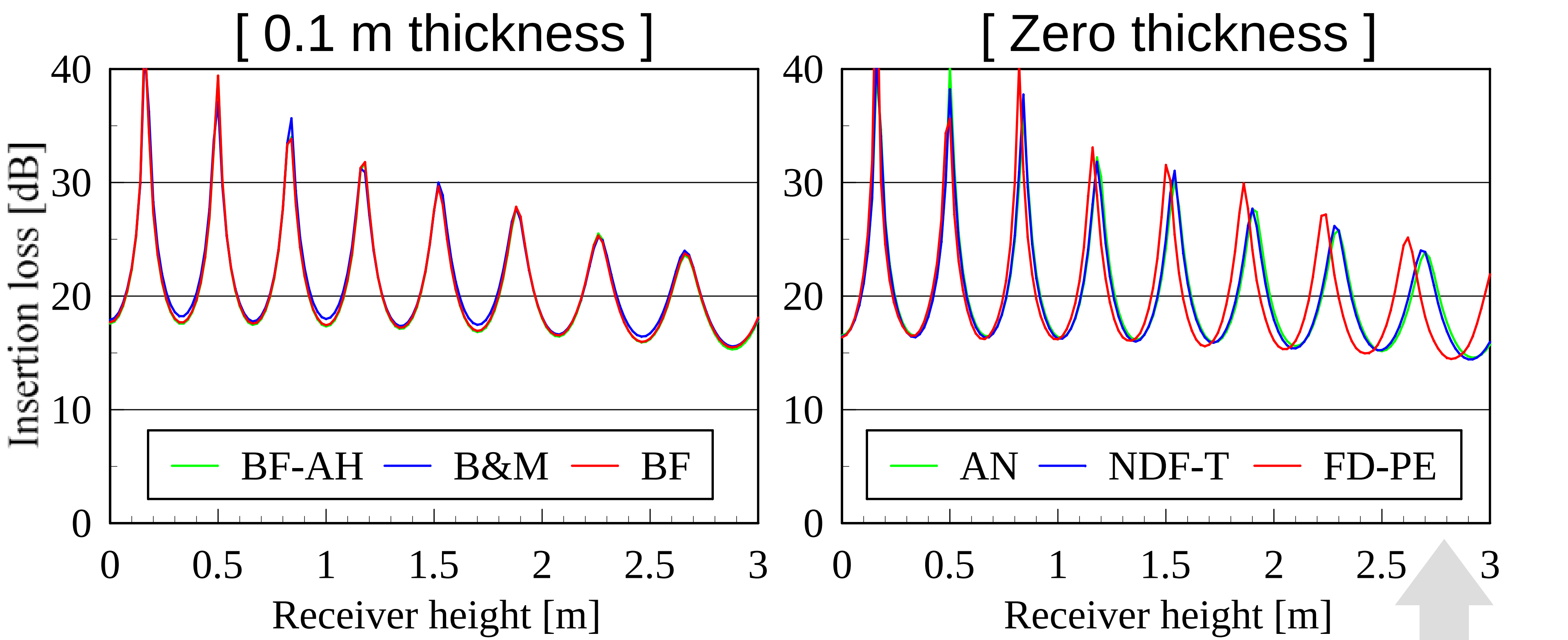


Contributed calculation results

Method		Abbrev.	A1-3F		A1-4F		A1-5F	
			A	B	A	B	A	B
Analytical solution		AN	○	○	○	○		
BEM	Basic Form	BF	○	○	○	○	○	○
BEM	BF with absorbing hollow	BF-AH	○	○	○	○	○	○
BEM	Burton & Miller method	B&M	○	○	○	○	○	○
BEM	Normal Derivative Form for rigid thin plate	NDF-T	○		○			
BEM	SYSNOISE Direct with CHIEF	SN-DC		○				
BEM	SYSNOISE Indirect	SN-ID		○				
FDTD-PE coupling		FD-PE	○	○				

Benchmarks allow 3-D analyses, but all contributions are in 2-D.

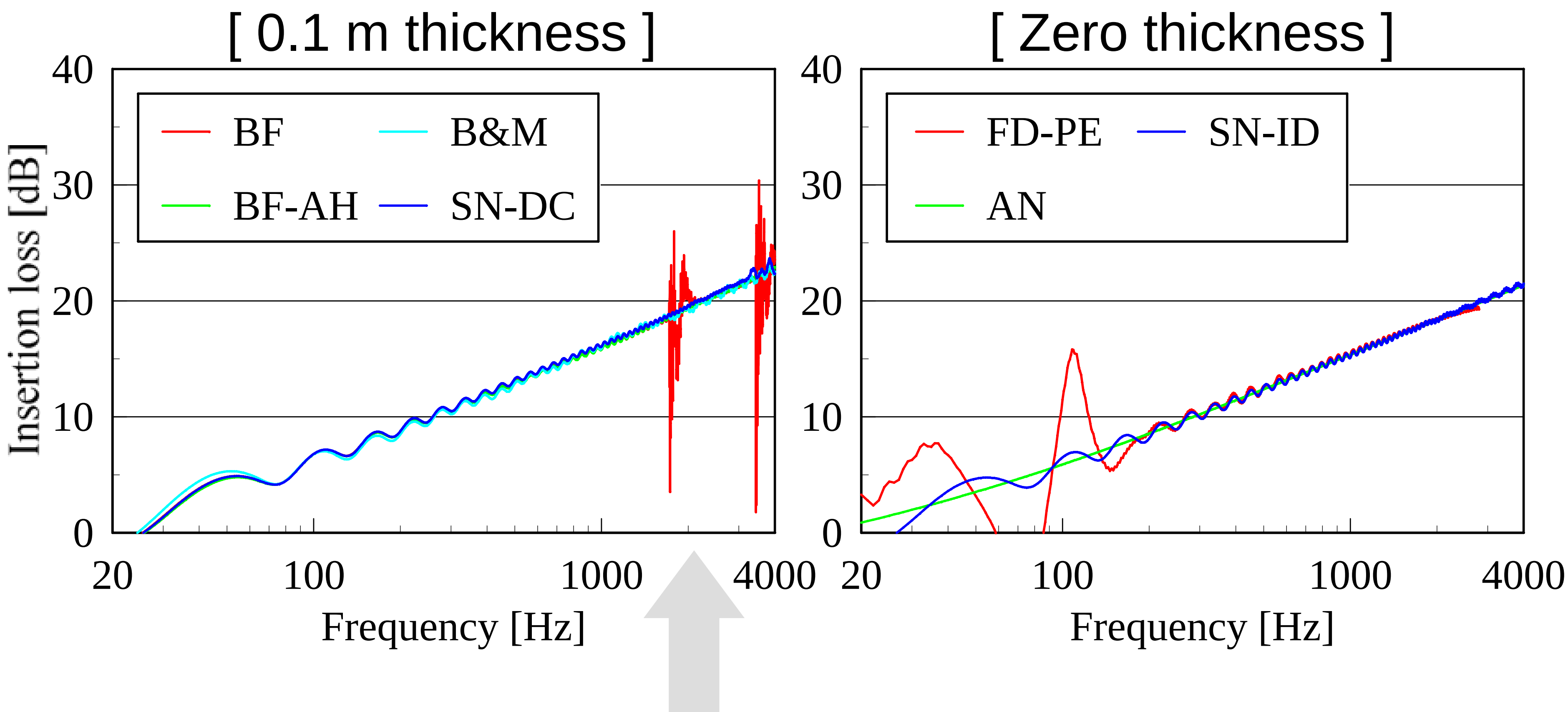
A1-3F-A: Along receiving line R1 at 1 kHz



FD-PE interference pattern shifts toward ground (probably caused by phase velocity error).

Simple barrier: IL frequency characteristics

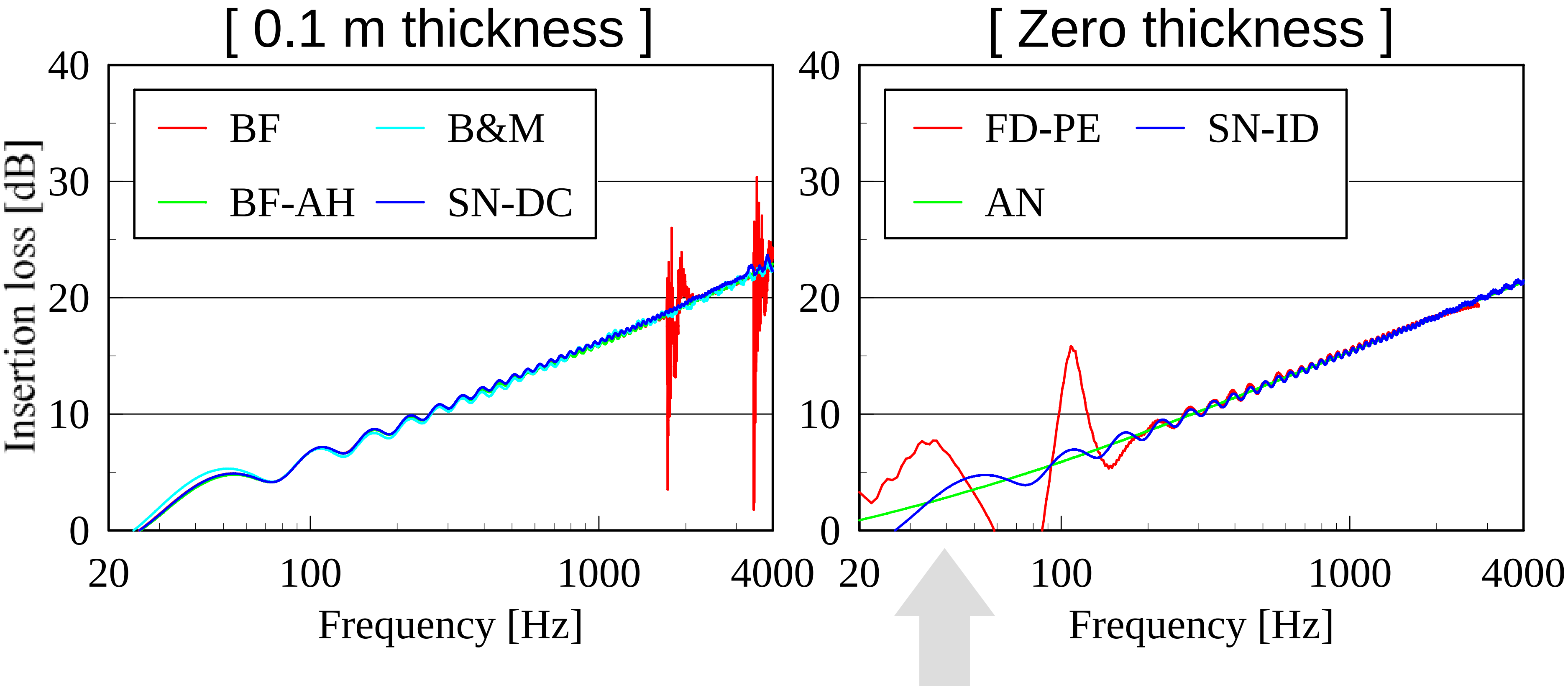
A1-3F-B: At receiver R3 (20 m)



BF suffers from non-uniqueness at high frequencies.
The other BEMs overcome non-uniqueness successfully.

Simple barrier: IL frequency characteristics

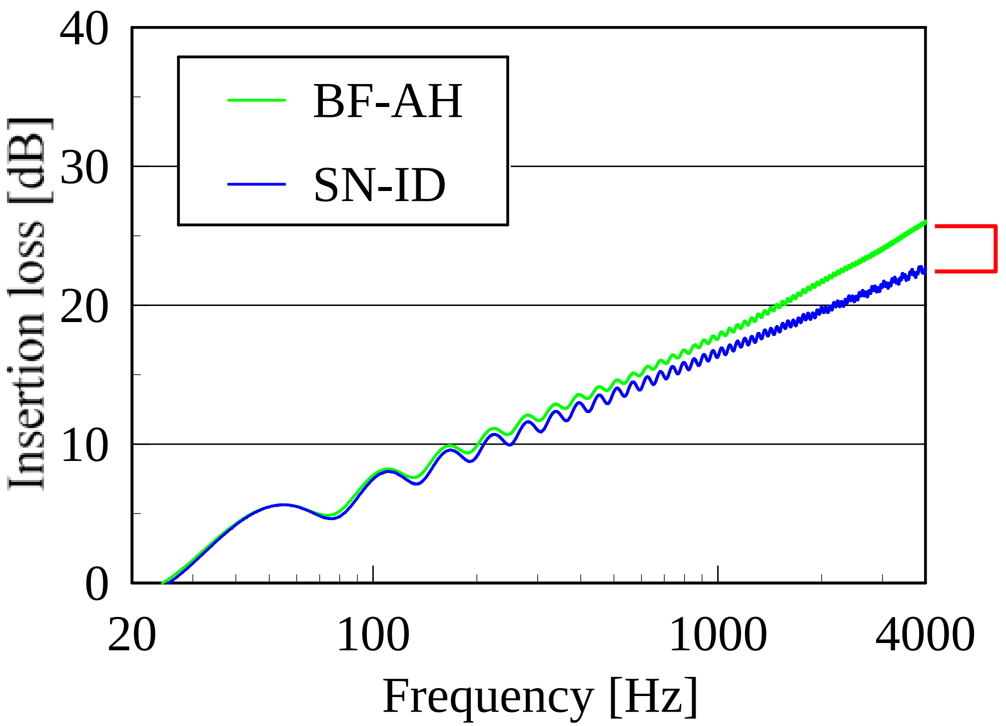
<u>A1-3F-B</u>: At receiver R3 (20 m)



SN-ID avoids non-uniqueness.
FD-PE deviates largely in low frequency range.
AN neglects the barrier-height interference.

Simple barrier: IL frequency characteristics

A1-3F-B: At receiver R2 (5 m)



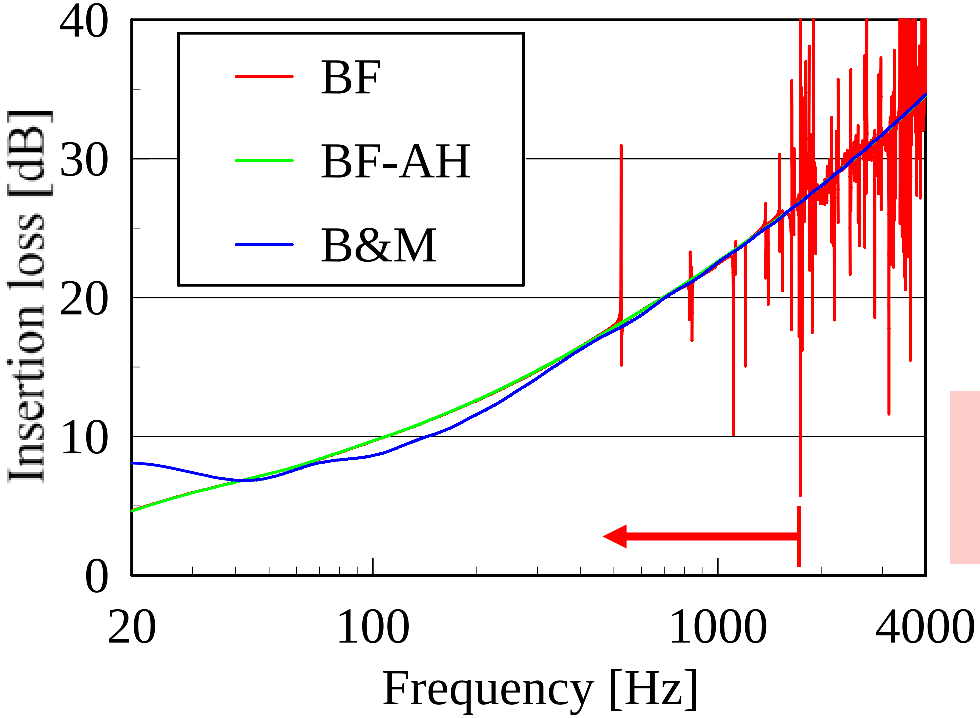
3.5 dB difference
by 0.1 m thickness

“Zero-thickness” approximation should be applied carefully.

1.5 dB at R3 (20 m); diffraction-angle dependent

Absorbing rounded-edge barrier: IL frequency charact.

A1-5F-B: At receiver R3 (20 m)



Still non-unique with absorbing boundary

Shift to lower frequencies by inner-volume increase

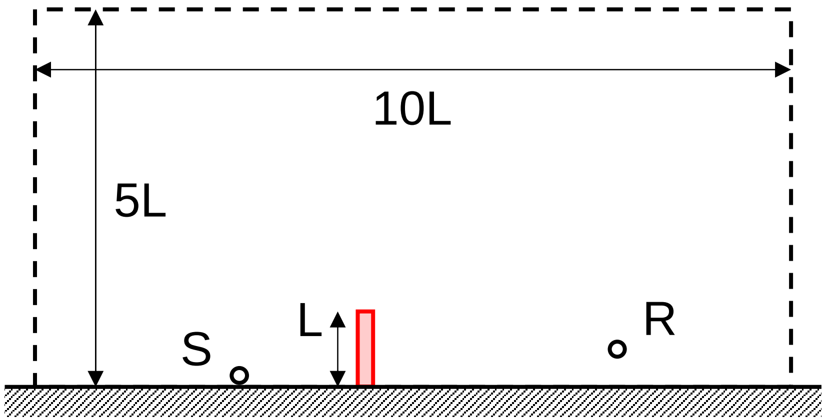
Non-uniqueness problem in BEMs

- Independent of boundary absorption.
- Arises in low frequency range by large inner volume.

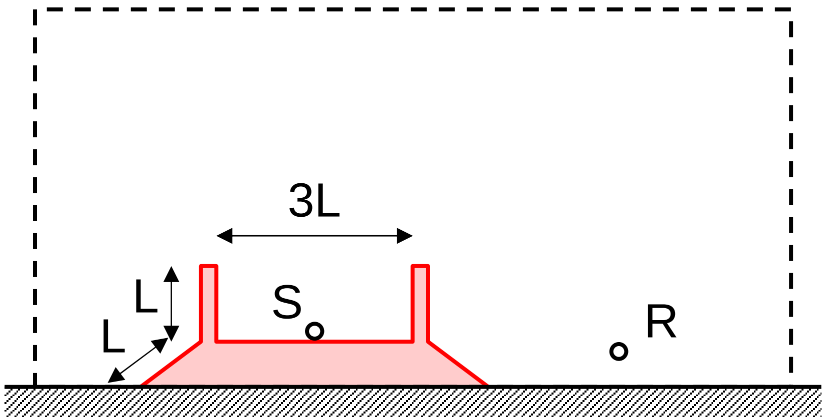
Factors of method selection: memory requirement

- Noise barriers in 2-D problem
- FDTD (3 REAL arrays) vs. BEM (1 COMPLEX array)
- Same size of grid and element, same precision of variables

[Flat terrain]



[Elevated road]



FDTD

$O(5L \times 10L \times 3) = O(150L^2)$

BEM

$O((2L)^2 \times 2) = O(8L^2)$

FDTD

$O(5L \times 10L \times 3) = O(150L^2)$

BEM

$O((9L)^2 \times 2) = O(162L^2)$

Factors of method selection: various BEMs

	Required memory (DOF = N)	To avoid non-uniqueness	
		Assurance	Implementation
Basic Form (BF), SYSNOISE Direct	$O(N^2)$	No	---
BF with CHIEF, SYSNOISE Direct with CHIEF	$O(N(N+N_C))$	Scheme-dependent	Easy
BF with absorbing hollow	$O(4N^2)$	Always	Very easy
Normal Derivative Form (NDF)	$O(N^2)$	No	(Singular integral)
NDF for rigid thin plate, SYSNOISE Indirect	$O(N^2/4)$	Always	Rigid boundary, singular integral
Burton & Miller method (BF-NDF coupling)	$O(N^2)$	Always	Singular integral, coupling factor

Summary

A series of benchmark platforms is established for exterior problems; basic shapes (cubes, spheres, flat panels) and practical shapes (diffusers, loudspeakers, noise barriers).

It is expected that accuracy and computational cost of each numerical method would be discussed by comparison in common benchmark platforms.

Results in this presentation are available in AIJ-BPCA website.