pemard
mediterranean acoustics research & development

Institute of Acoustics

OLIVE TREE LAB SUITE

An integrated approach to Acoustics - sound propagation and the phenomena affecting it

IOA LONDON BRANCH EVENING MEETING,

WSP | PARSONS BRINCKERHOFF

PRESENTATION BY PANOS ECONOMOU OF PEMARD, 19TH APRIL 2017

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS

IMPEDANCE VS ABSORPTION COEFFICIENT

REVIEWS OF MODERN PHYSICS, VOLUME 16, NUMBER 2 APRIL, 1944,
Sound Waves in Rooms, PHILIP M. MORSE AND RICHARD H. BOLT

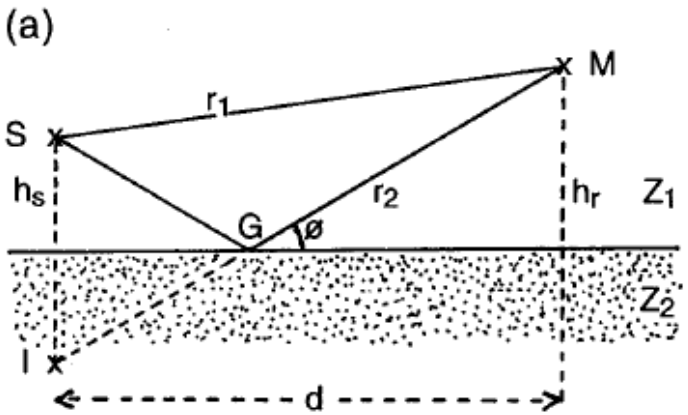
Morse and Bolt in their 1944 paper say on page 87: "*It has been demonstrated in a number of ways that the absorption coefficient entering into the geometrical acoustical formulas is not a fundamental property of the wall surface…. It is an average property, averaged for the particular distribution of sound which we have called "ergodic" in the previous section, and has no meaning in cases where the sound distribution is not ergodic. It is well to emphasize this limitation on the use of the term absorption coefficient, for an over-optimistic use of the term may lead to erroneous results…. It is true that the impedance is not a much more "fundamental" physical property than the absorption coefficient; its advantage lies in the fact that its measurement can be specified concisely and uniquely and that its value for a given material has a definite meaning no matter what the distribution of sound inside a room.*"

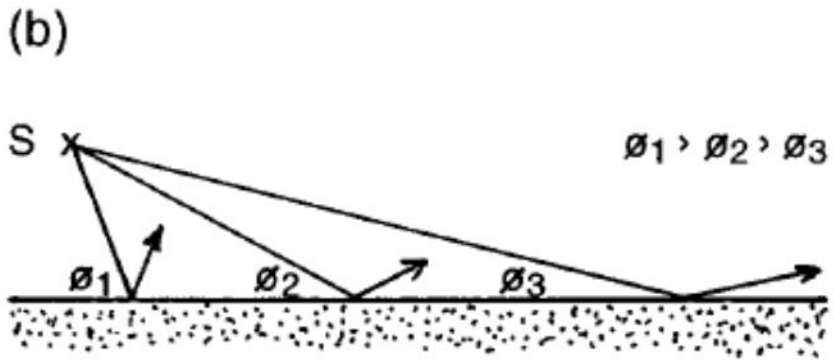
PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS

SPHERICAL & GROUND WAVES

"…Practically, one never has plane waves. They are a mathematical fiction which can be only approximated physically."
Isadore Rudnick, 1947, JASA VOLUME 19, NUMBER 2, "The Propagation of an Acoustic Wave along a Boundary"

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS





"A ground wave occurs when the incident sound field spreads spherically, as from a small source near the ground, and so reaches different parts of a plane surface with different angles of incidence. Changing angles of incidence produce a reflection coefficient that varies with position along the surface….The result is that there cannot be an image I in the ground that is spatially a replica of the true source S, and not even one of reduced strength. Theoretical analysis shows that there is a ''fuzzy'' image distributed over an extensive region. It is strongest at the expected location but extends to infinity both horizontally and downward."

Tony F. W. Embleton: Sound propagation outdoors

J. Acoust. Soc. Am., Vol. 100, No. 1, July 1996

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS

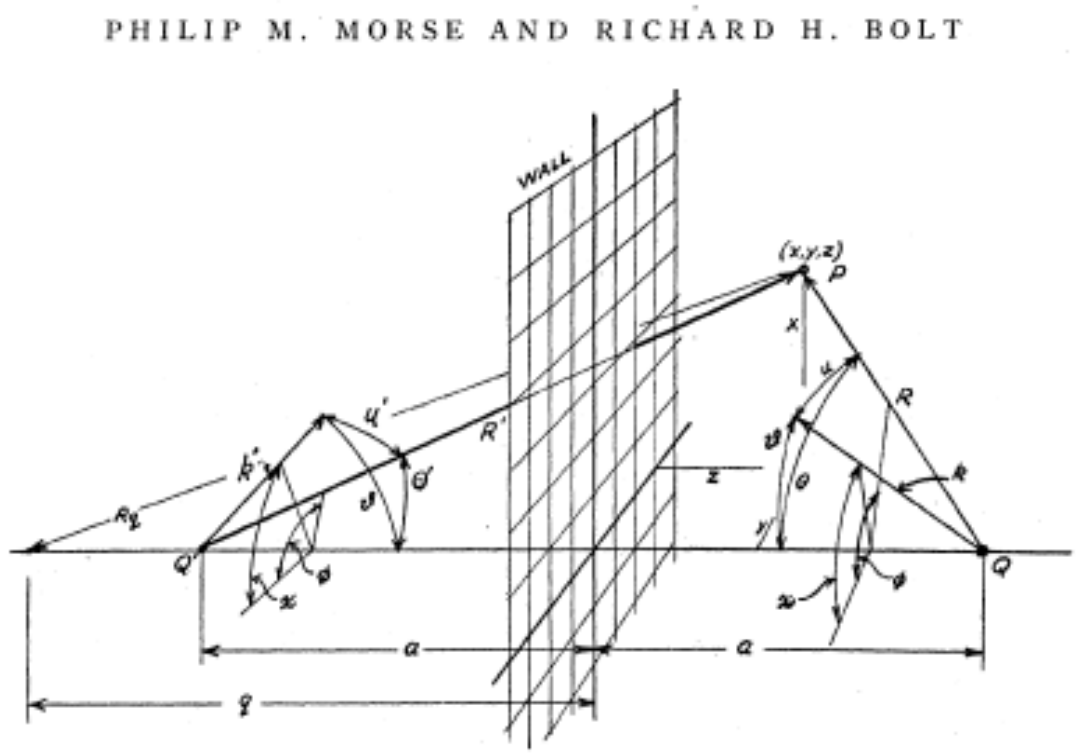


FIG. 31. Angles and distances involved in computing the reflection of a spherical wave from an absorbing wall.

"Therefore any argument which assumes that the reverberant sound can be represented by a multiplicity of simple images is likely to lead to fallacious results. The analyses of Sabine, Norris, Eyring, Millington, and Sette are subject to this criticism".

REVIEWS OF MODERN PHYSICS, VOLUME 16, NUMBER 2 APRIL, 1944, Sound Waves in Rooms, PHILIP M. MORSE AND RICHARD H. BOLT

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS

Theodore J. Schultz in his paper *“Persisting questions in steady-state measurements of noise power and sound absorption” starts with, “….in view of the great number of recent studies on this subject, the reverberation room seems to be turning into a "research object" rather than a "useful tool." ….it is almost incredible to me that we could produce such a complex and mysterious thing, just by putting up four walls, a floor and a ceiling, and then radiating sound into it. And yet the more we study sound in an enclosed space, the more peculiar it seems. If our earlier theories made the behavior of sound in rooms appear simple, our recent studies are certainly correcting that naive view.”*

“Persisting questions in steady-state measurements of noise power and sound absorption” Theodore J. Schultz, JASA Volume 54 Number 4 1973

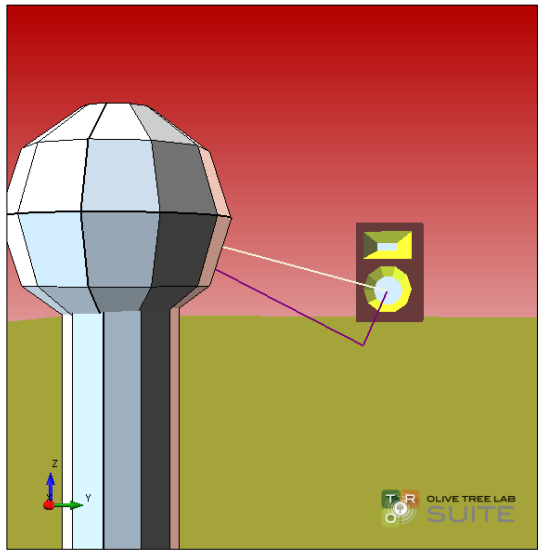
PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

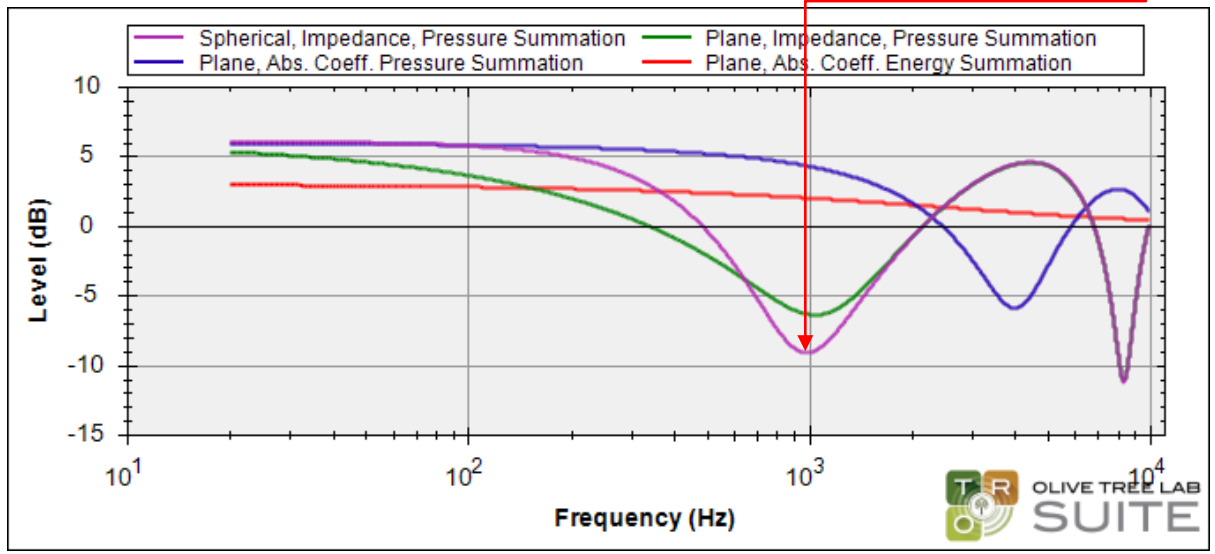
A REFLECTION OVER A SURFACE –
IS THERE MORE THAN ONE ANSWER TO THE PROBLEM?

PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

1: Spherical wave, Impedance, pressure summation

The figure on the left shows the configuration while the figure on the right Excess Attenuation in dB (the ratio of total over direct sound field).

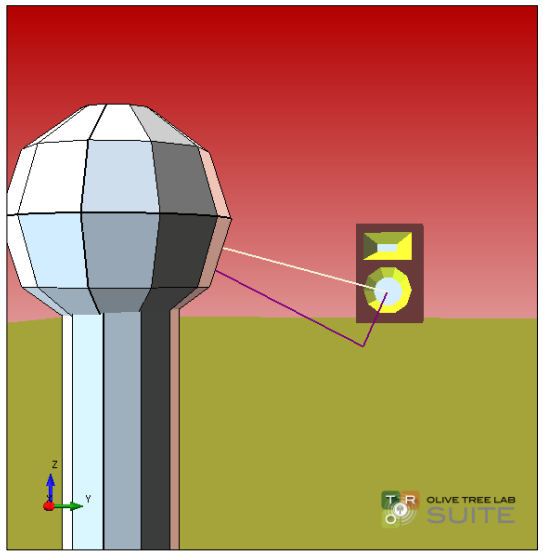


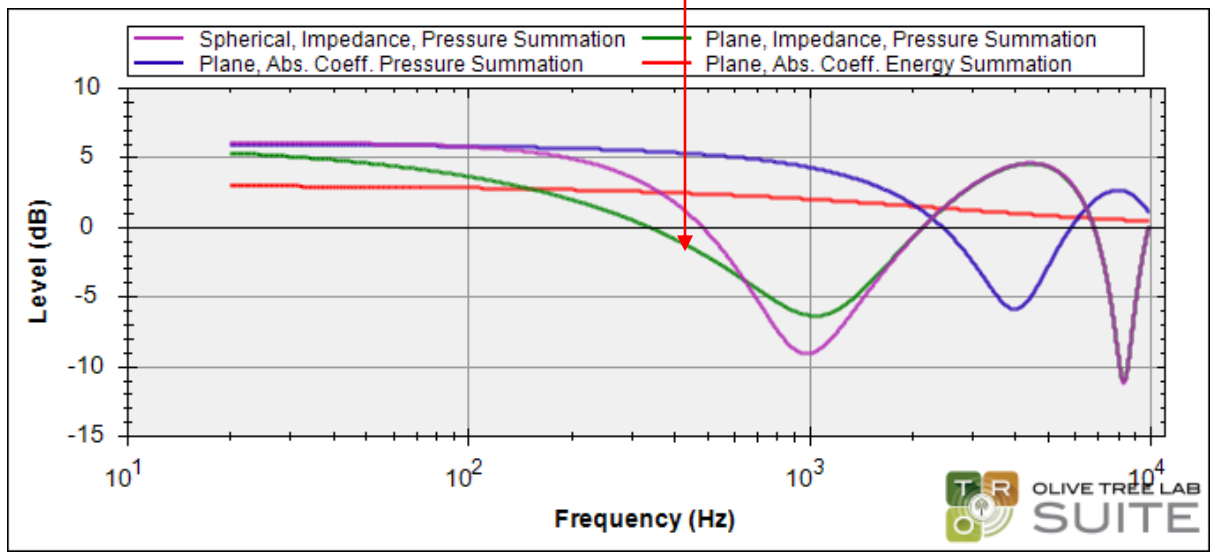


ROOM RESONANCES USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

2: Plane wave, Impedance, pressure summation

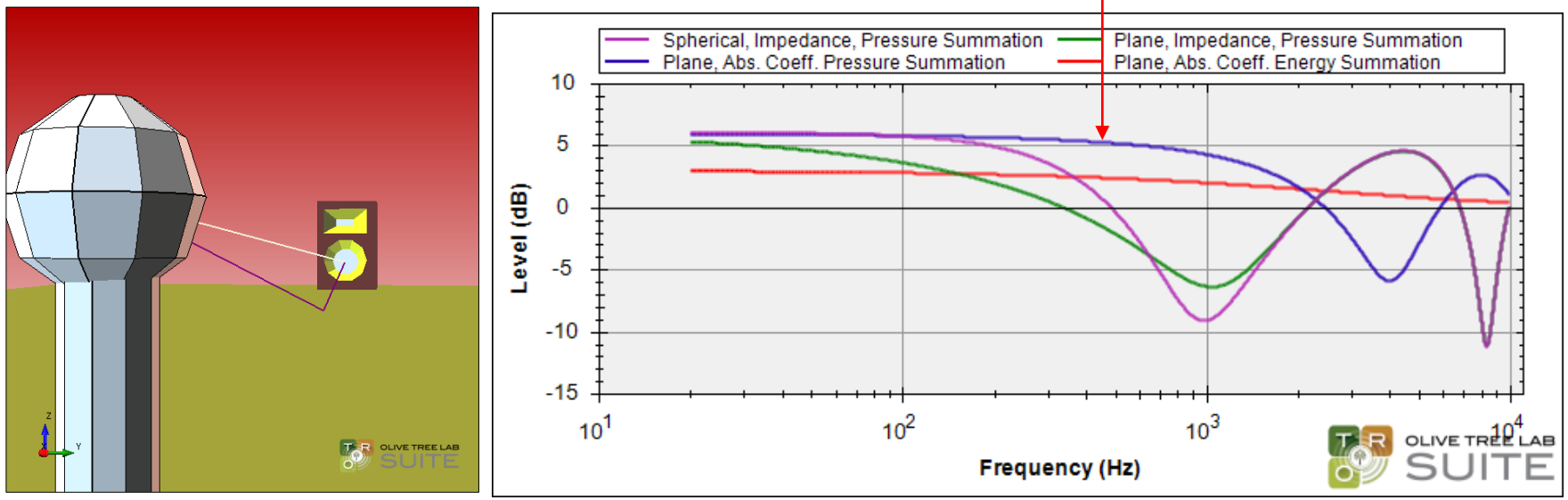




ROOM RESONANCES USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

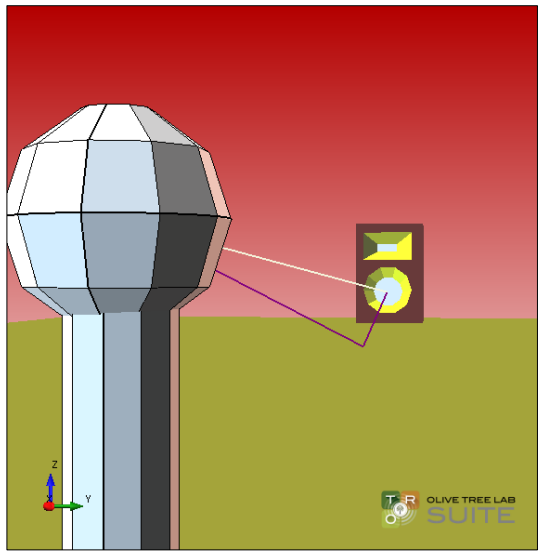
3: Plane wave, absorption coefficient, pressure summation.

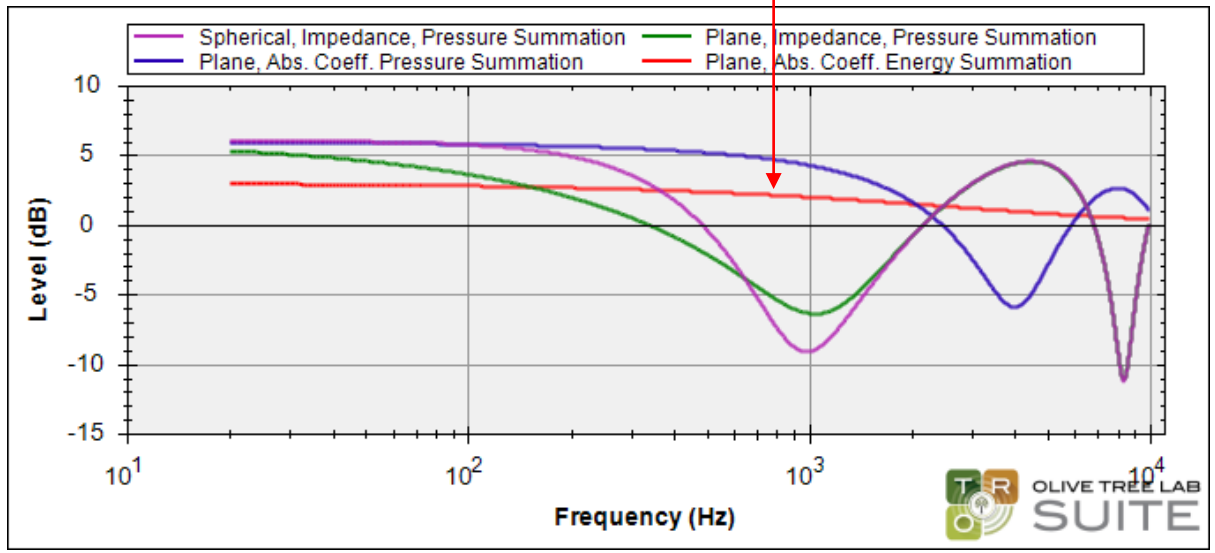


ROOM RESONANCES USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

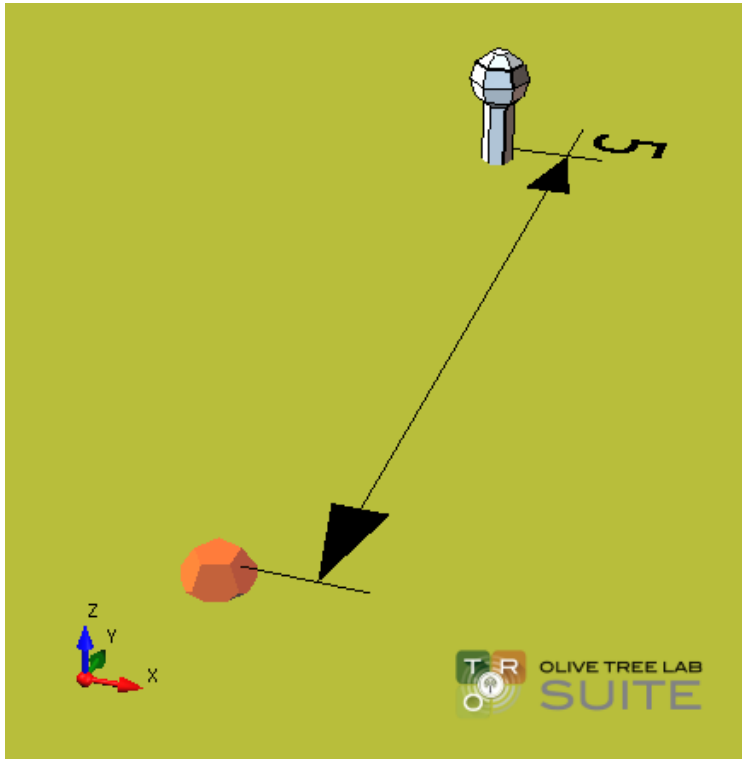
4: Plane wave, absorption coefficient, energy summation.

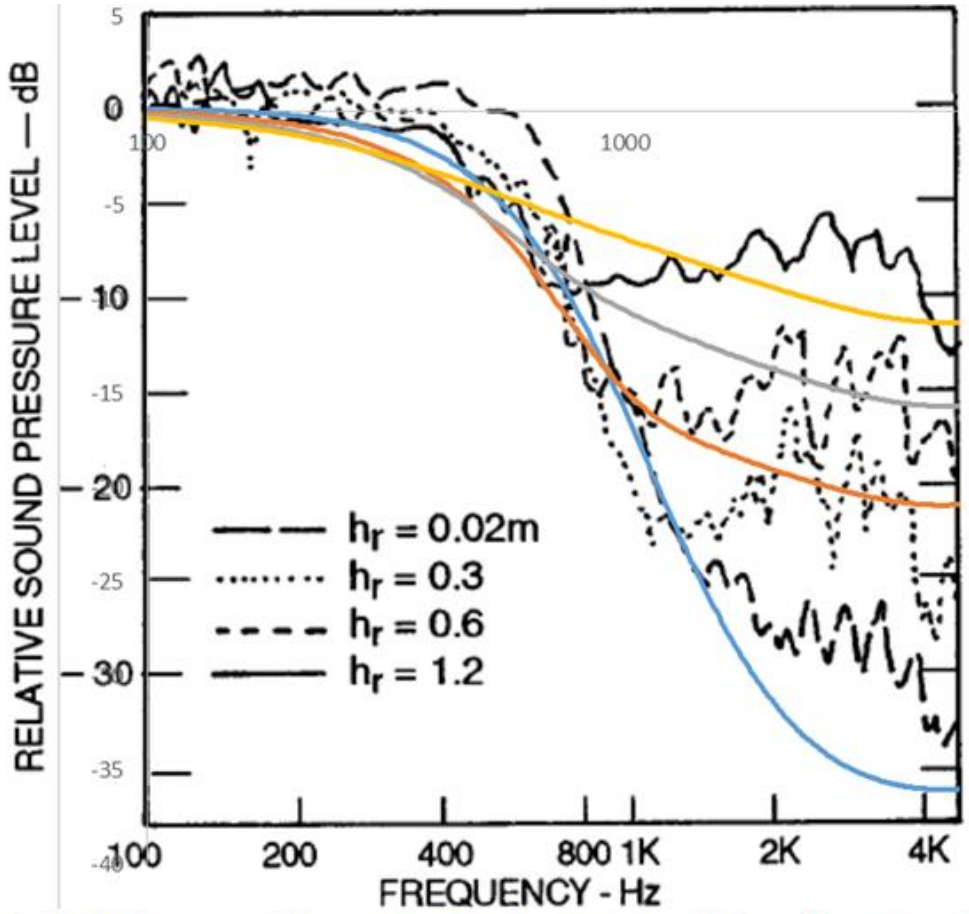




ROOM RESONANCES USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS





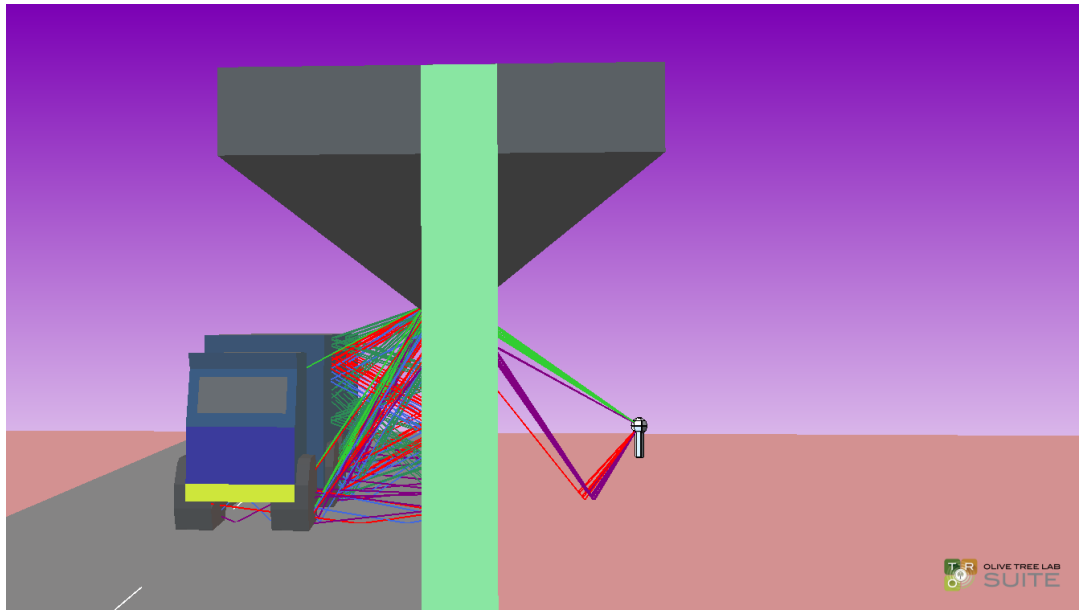
Tony F. W. Embleton: Sound propagation outdoors
J. Acoust. Soc. Am., Vol. 100, No. 1, July 1996

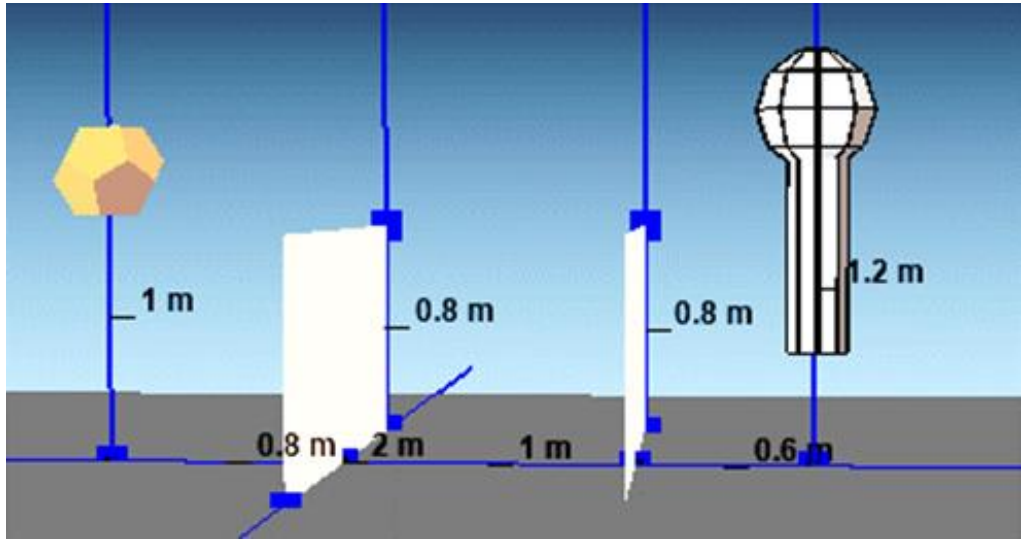
FIG. 6. Relative sound pressure levels measured 5 m from a point source at the surface of an acoustically soft ground (grass). Results are for four different receiver heights, h_r=0.02, 0.3, 0.6, and 1.2 m, respectively (Ref. 13, Fig. 5).

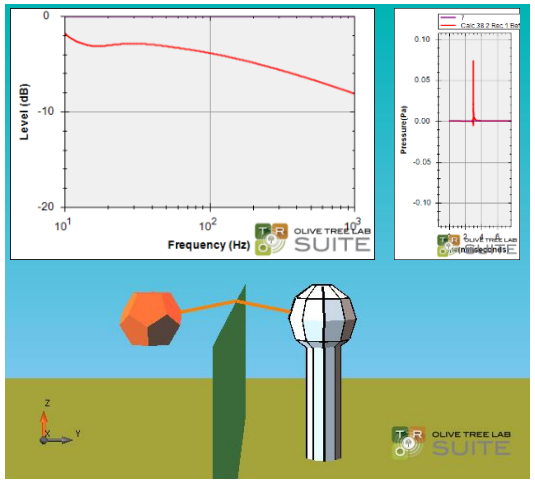
PART 1: INTRODUCTION – ACOUSTICAL CURIORSITIES

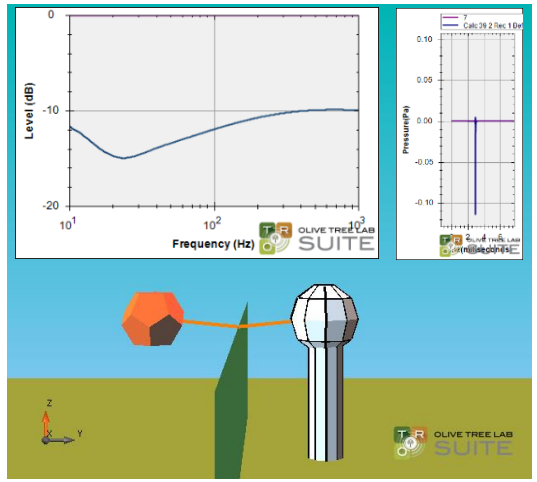
SOUND DIFFRACTION

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS



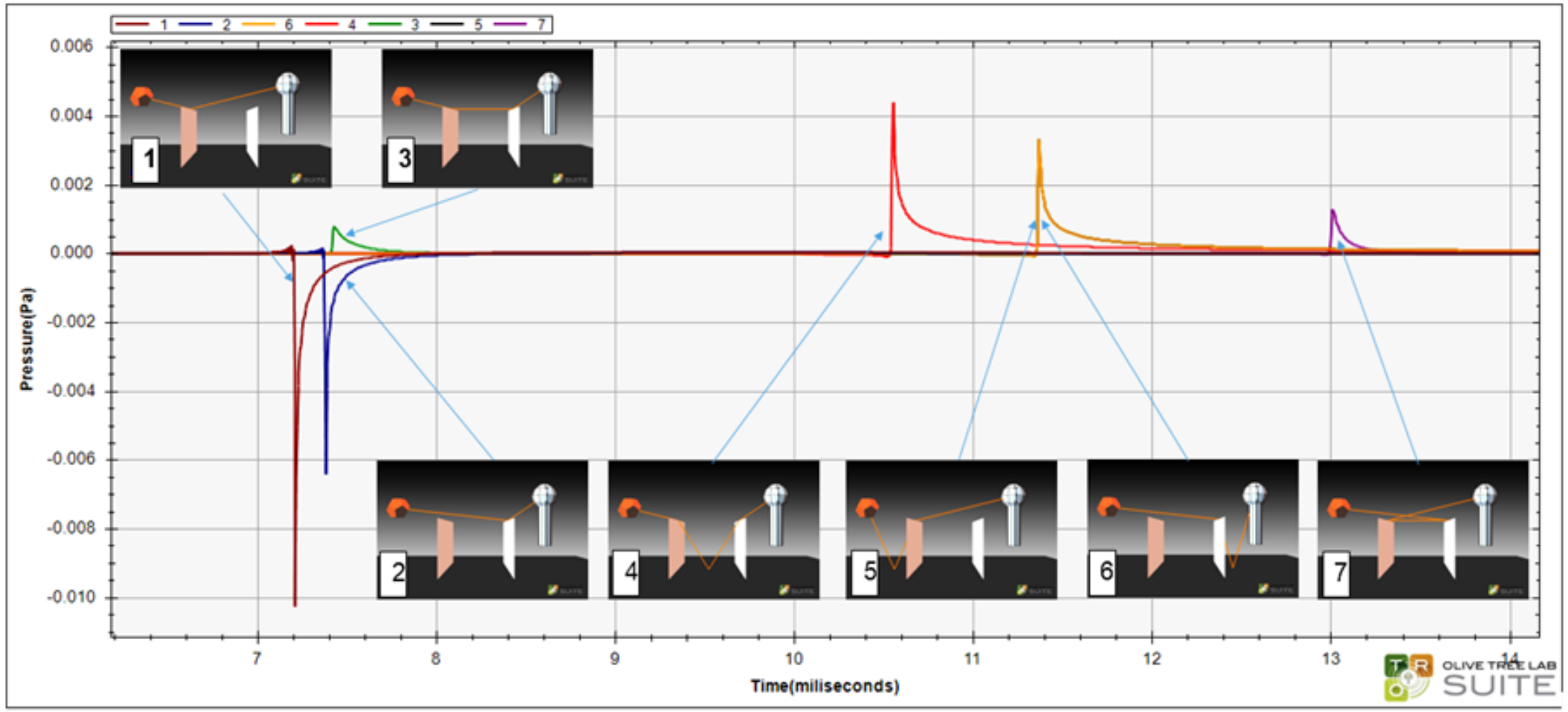






THE SEAT DIP EFFECT USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 1: INTRODUCTION – FROM OPEN SPACES TO ROOMS



THE SEAT DIP EFFECT USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

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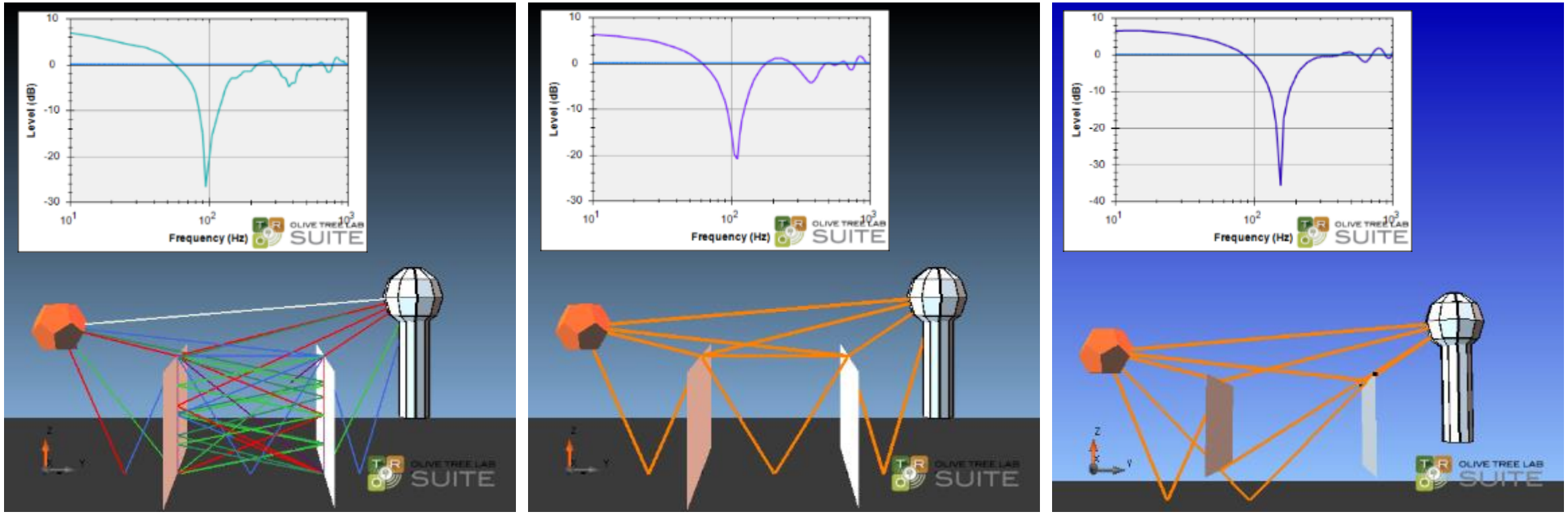


THE SEAT DIP EFFECT USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

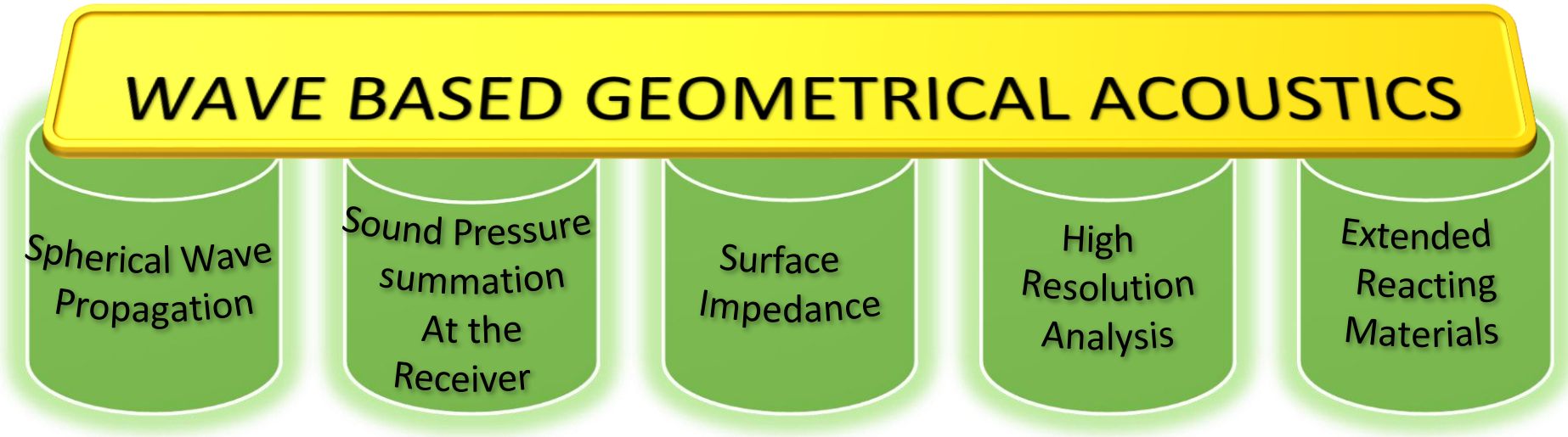
PART 2: PEMARD APPROACH

THE
P. E. MEDITERRANEAN ACOUSTICS RESEARCH & DEVELOPMENT
(PEMARD) APPROACH

PART 2: PEMARD APPROACH

What is Wave Based Geometrical Acoustics (WBGA)?

It is the method by which the calculation of acoustical fields take into account the principle of superposition of waves using both amplitude and phase, producing interference phenomena.



PART 2: PEMARD APPROACH

SOUND REFRACTION IN THE ATMOSPHERE

PART 2: PEMARD APPROACH

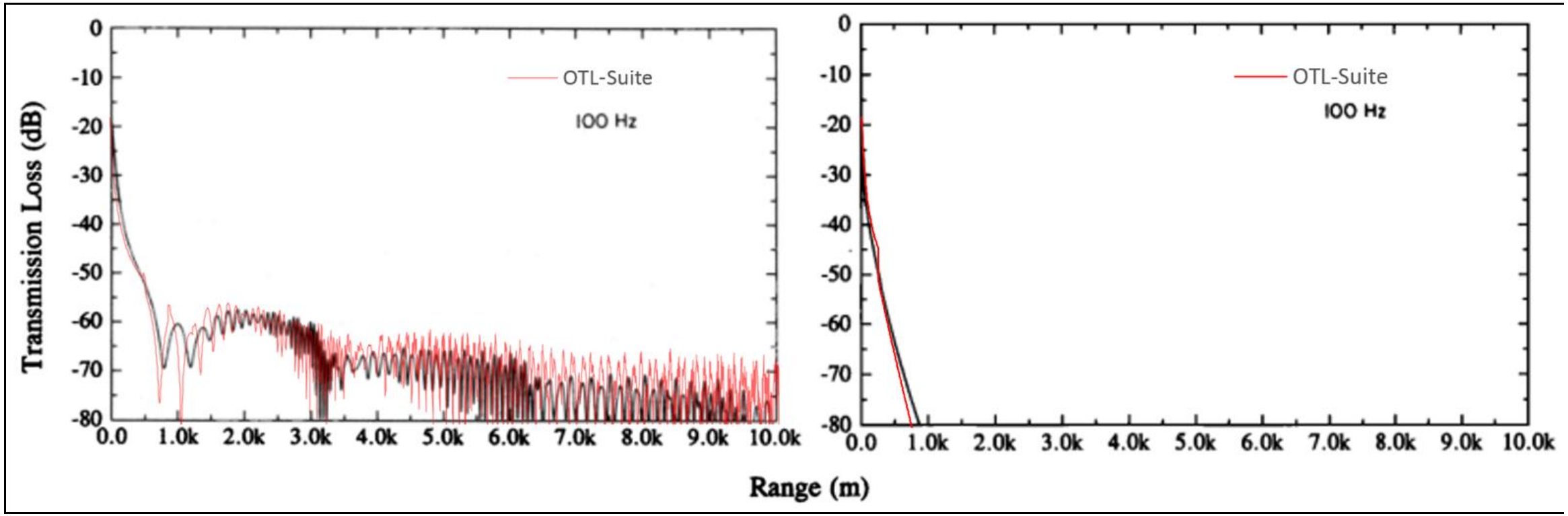
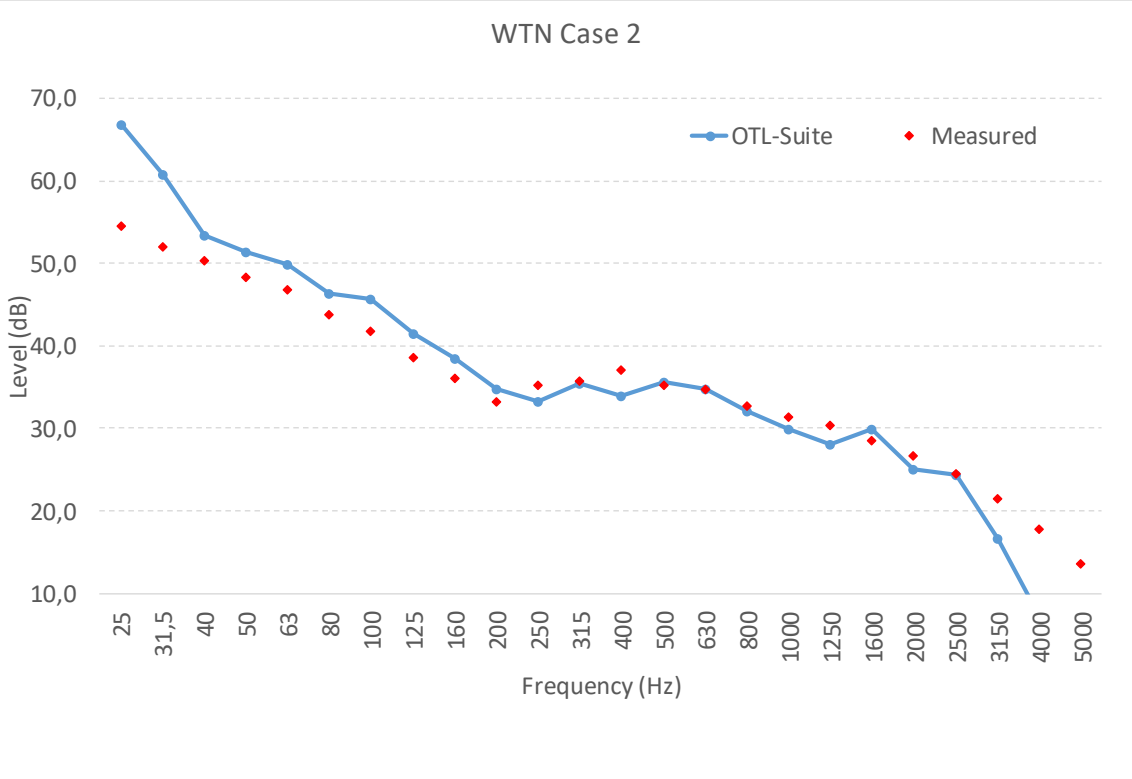


Figure 2: Comparison between OTL-Suite calculations (red line) and 1995 Benchmark Cases (black line). Left graph is for the case of a strong positive linear sound speed gradient of 0.1 s^{-1} while the right graph is for the case of a strong negative sound speed gradient of -0.1 s^{-1}. Both curves show transmission loss vs distance at 100Hz. Calculated graphs are superimposed on published data.

WIND TURBINE NOISE PREDICTION USING OLIVE TREE LAB TERRAIN, WTN, INCE-EUROPE , BIGOT, ECONOMOU, MAY 2017

PART 2: PEMARD APPROACH



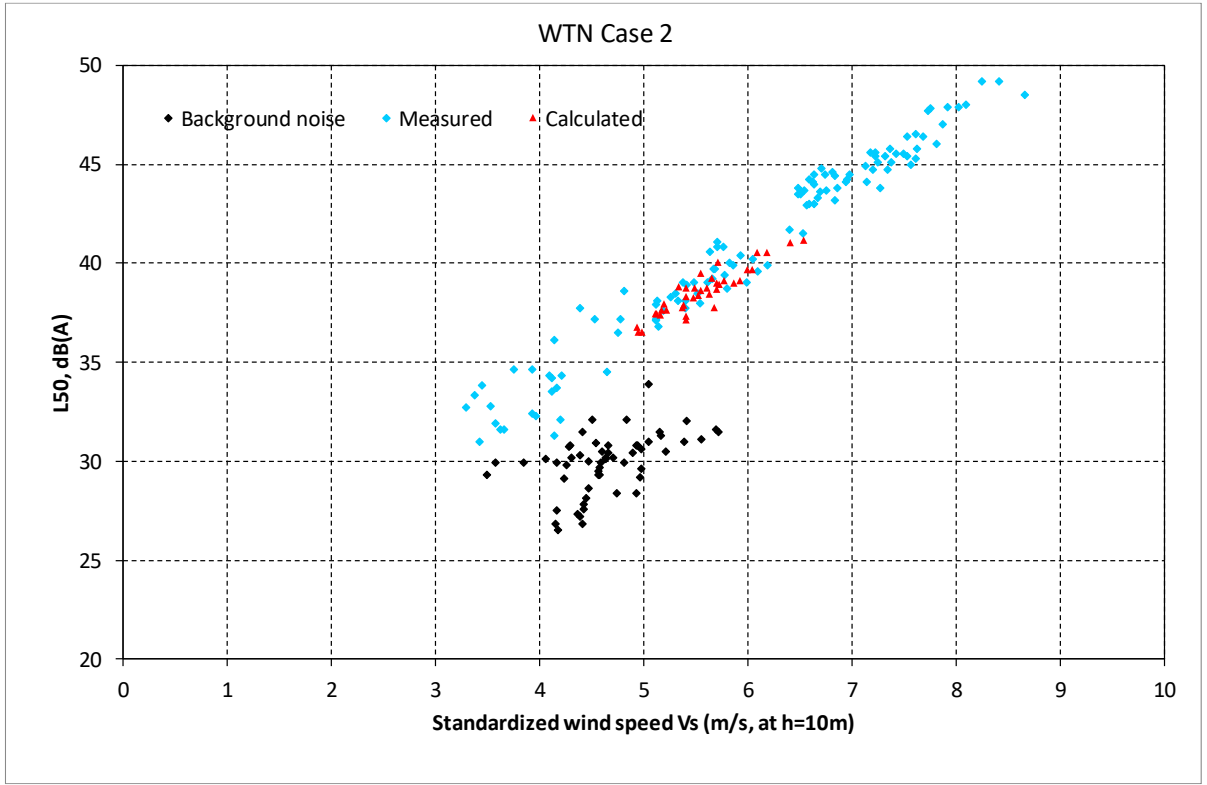
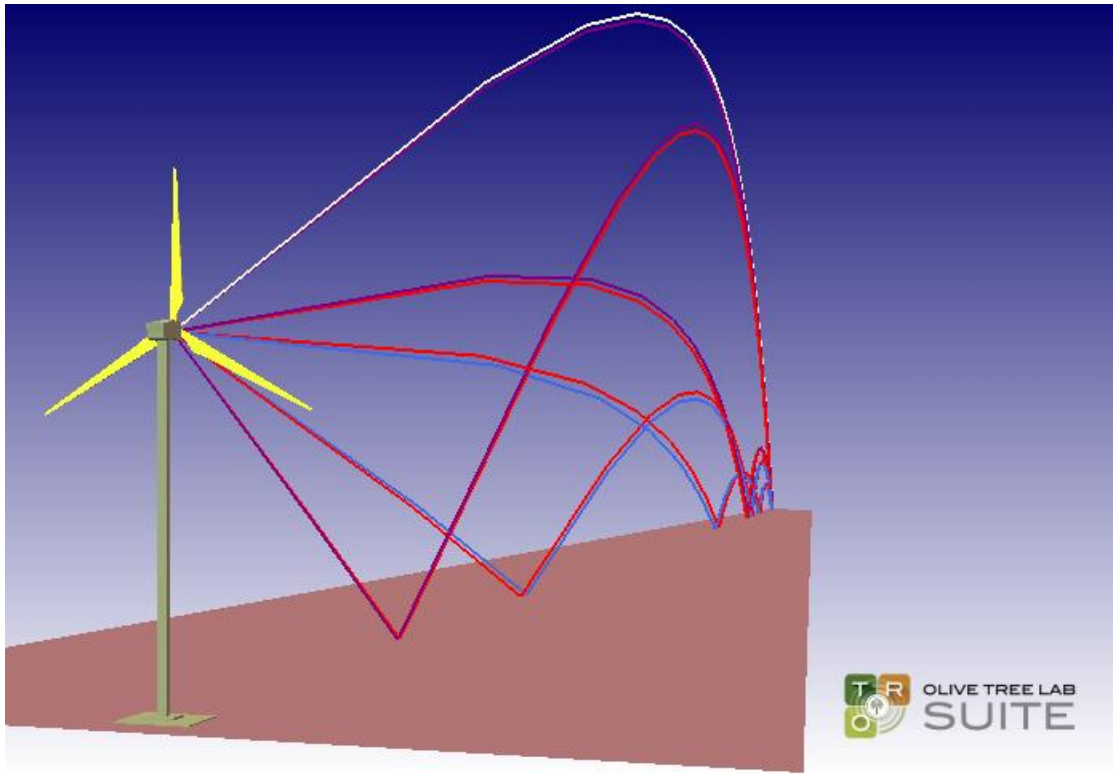
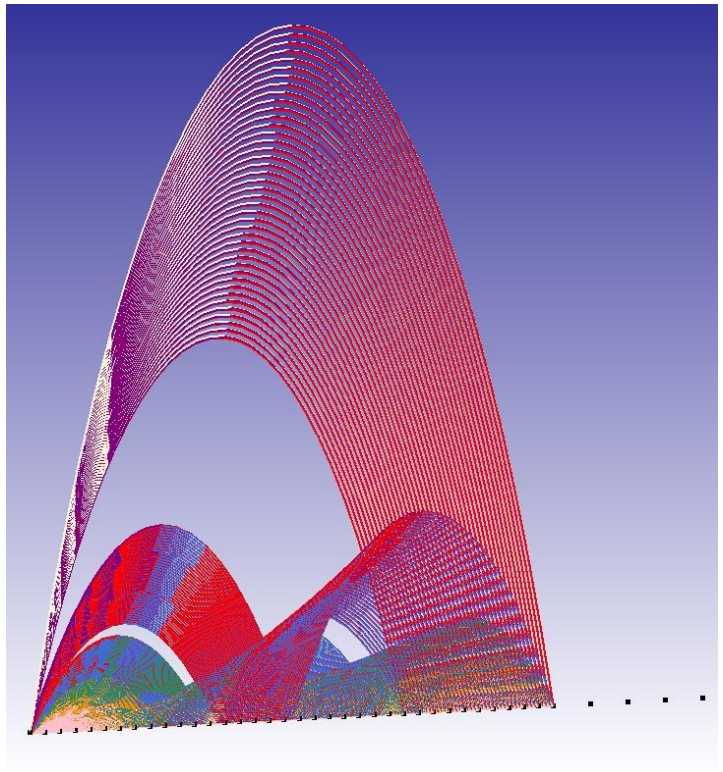


Figure 7: Left graph: Measured and predicted noise levels for WTN Case 2. Right graph: Measured and predicted Noise Levels for Case 2 in dB(A) for a set of 10-minute meteorological data. Downwind conditions with a range of 500m.

PART 2: PEMARD APPROACH

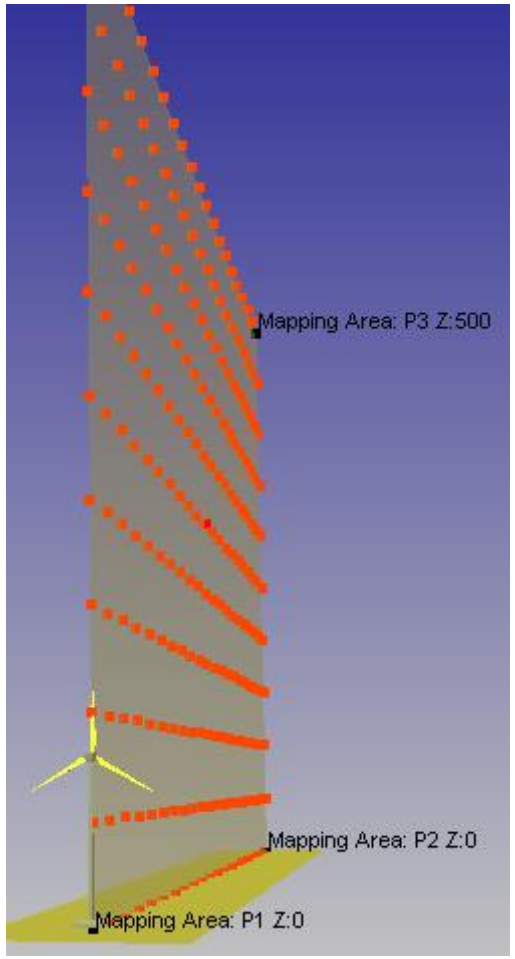


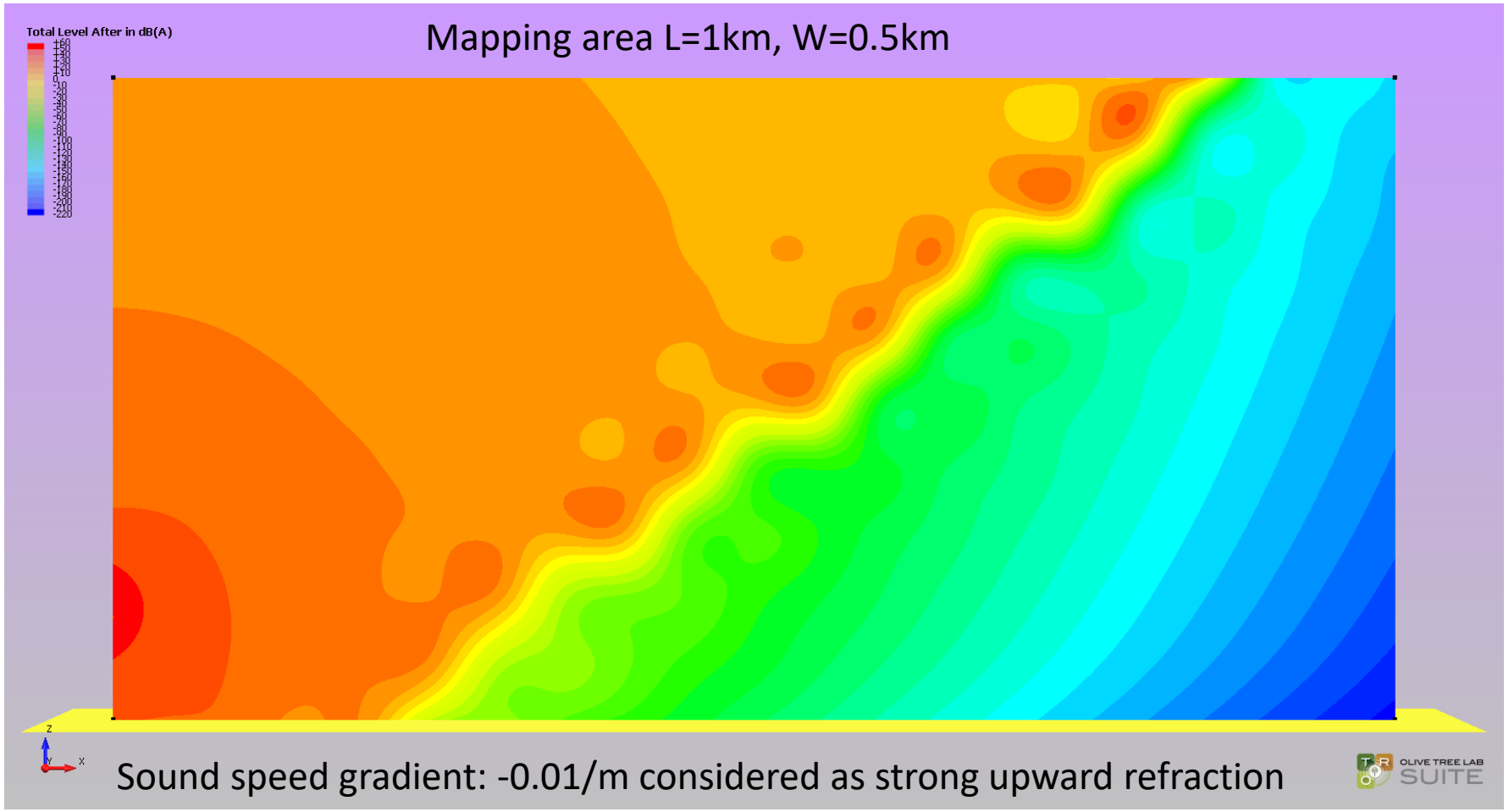


Bent sound rays and multiple ground reflections due to downwind conditions, On the left, few rays for clarity and on the right 1000 sound paths.

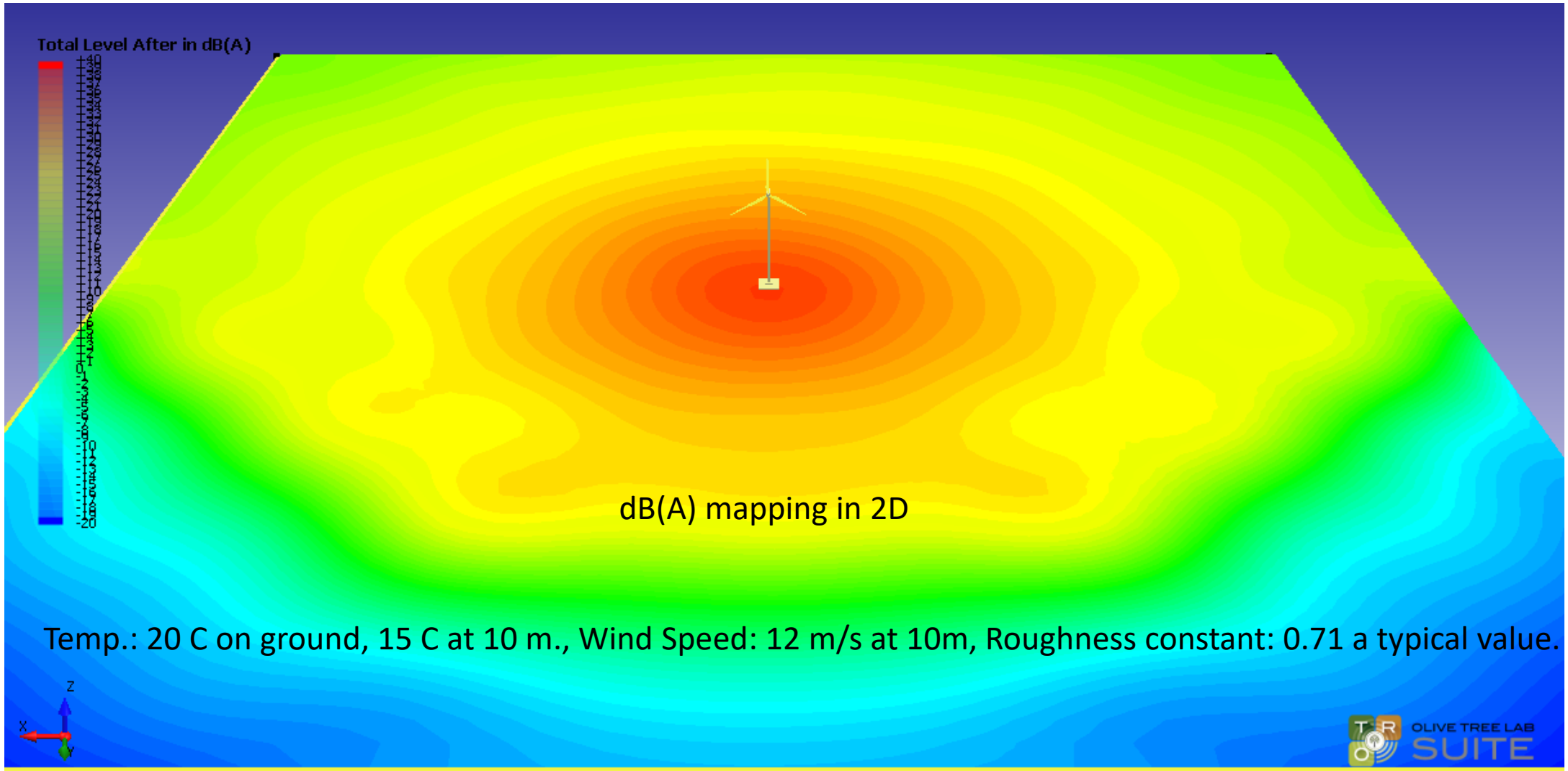
WIND TURBINE NOISE PREDICTION USING OLIVE TREE LAB TERRAIN, WTN, INCE-EUROPE , BIGOT, ECONOMOU, MAY 2017

PART 2: PEMARD APPROACH





PART 2: PEMARD APPROACH



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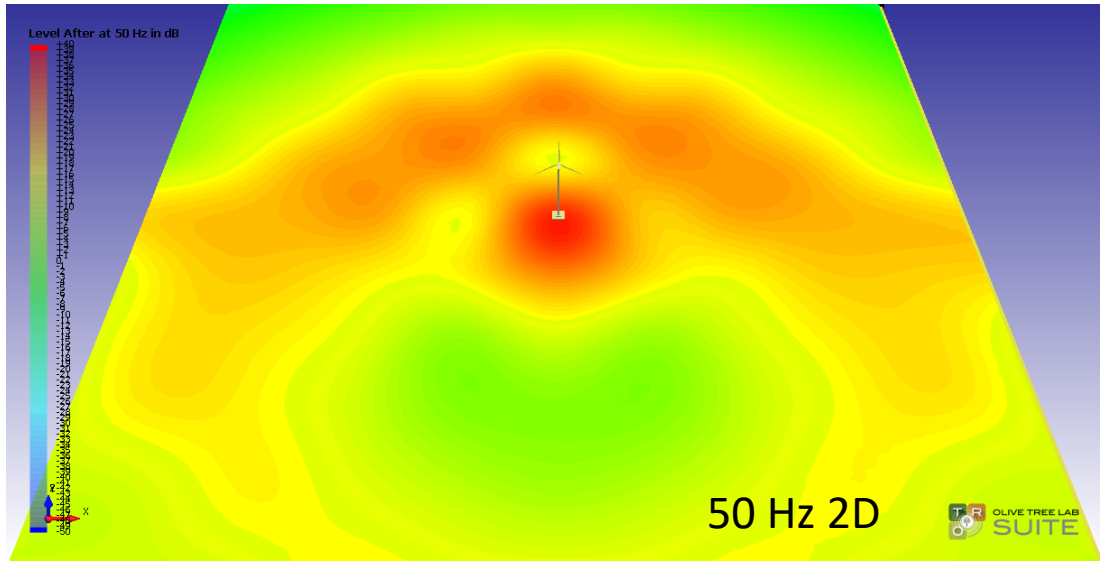
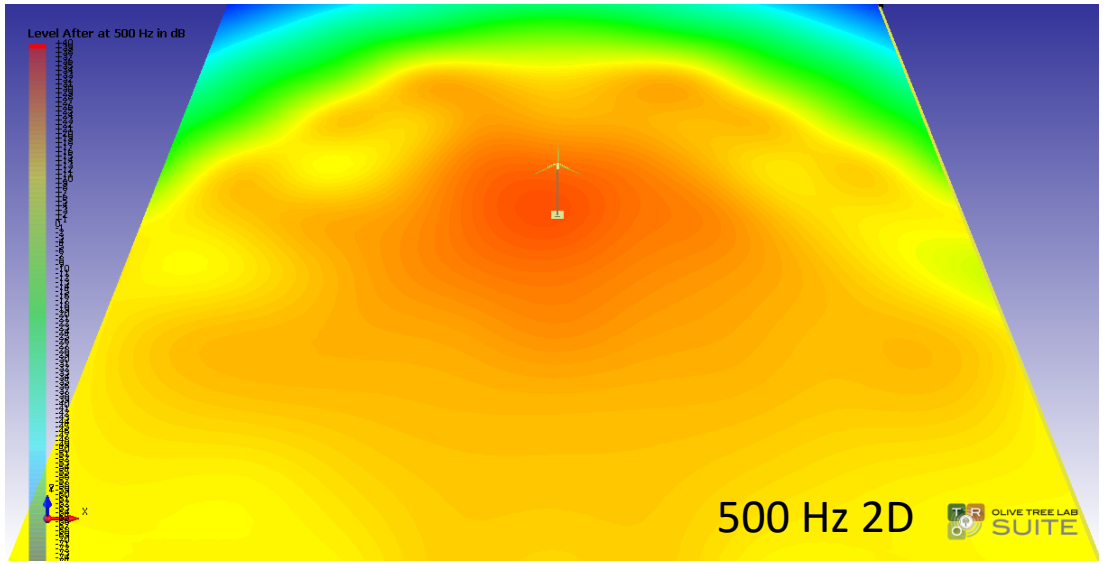
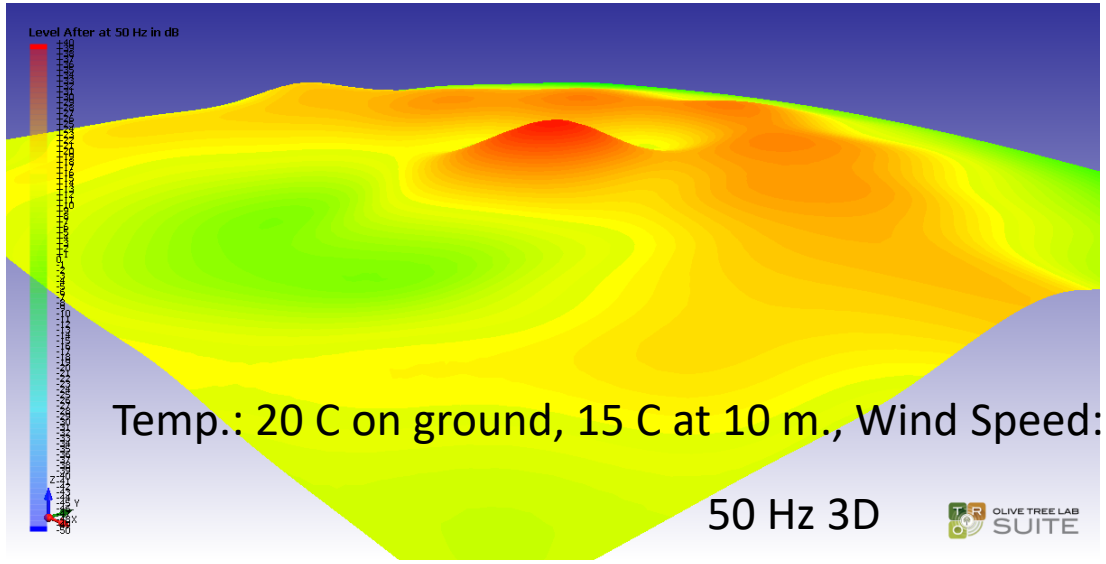
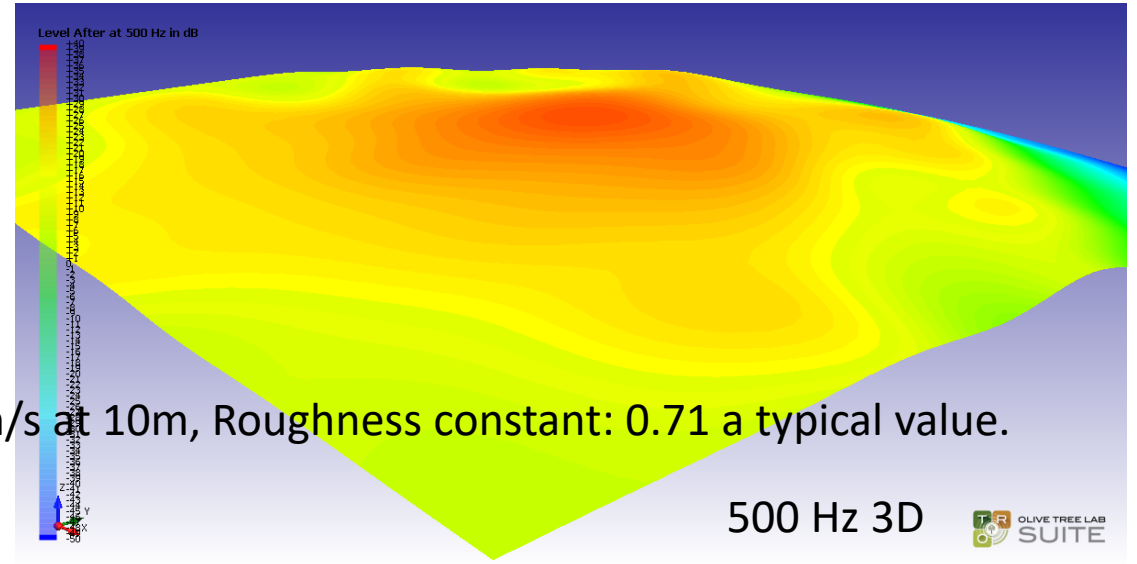








Temp.: 20 C on ground, 15 C at 10 m., Wind Speed: 12 m/s at 10m, Roughness constant: 0.71 a typical value.

PART 2: PEMARD APPROACH

ISO 9613 vs PEMARD APPROACH

PART 2: PEMARD APPROACH

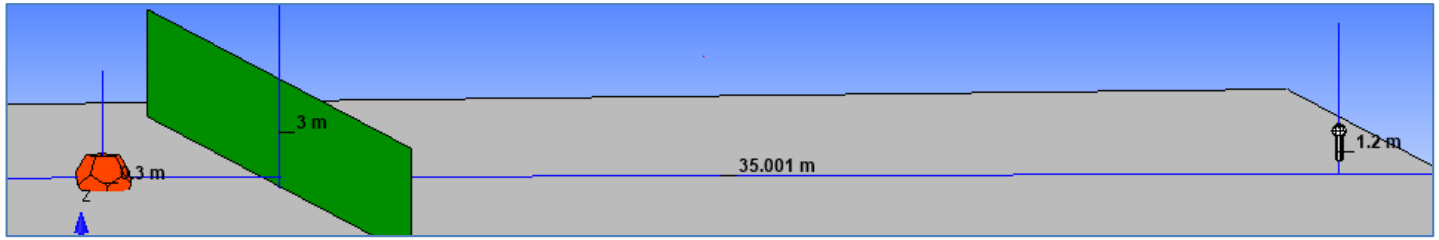
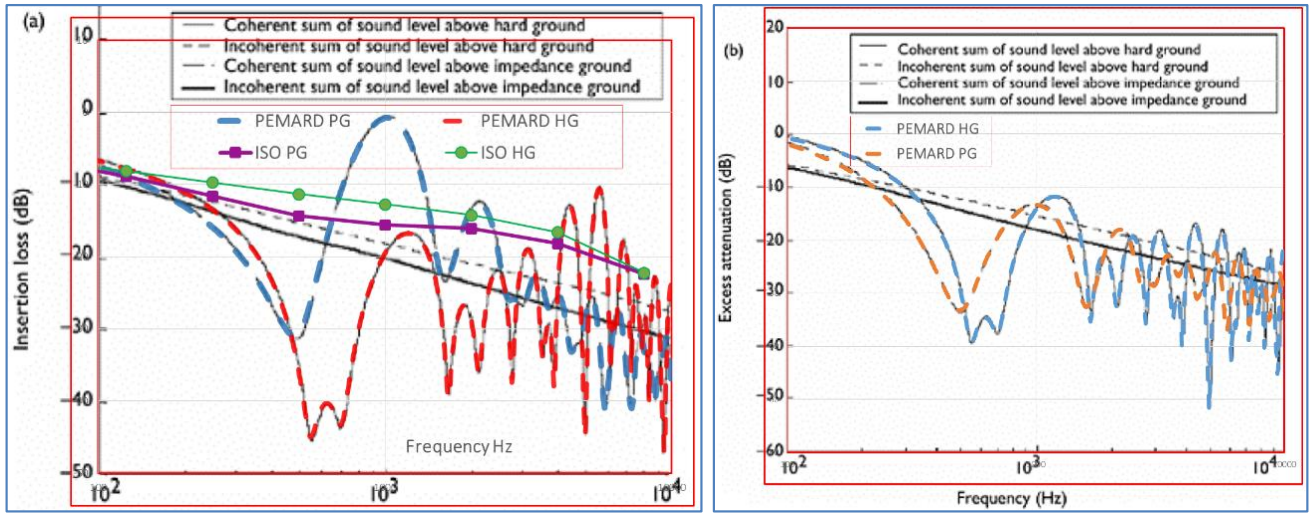


Figure 1: Geometry of set up in Terrain, Hs=0.3m, Hr=1.2m, Hb=3m, Dsr=35m, HG=GFR=20 MNs/m^4, PG=GFR=300 kNs/m^4



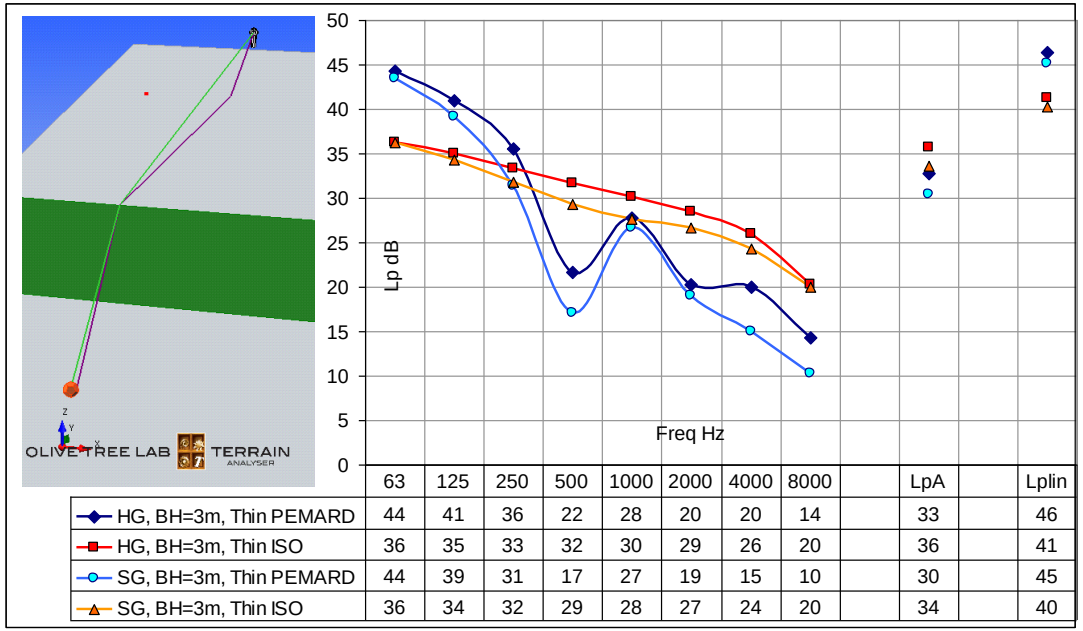
(a) (b)

Figure 2: Validation of Isei's geometry from **Error! Reference source not found.**. Calculations are superimposed on graph courtesy of Attenborough et. al. (a) Insertion loss of barrier with Hard and Porous Ground effects. In colored dashed lines PEMARD results which are almost indistinguishable from the original graphs, in solid lines and markers the ISO results. (b) Excess Attenuation with barrier in place, colored dashed lines represent PEMARD results.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

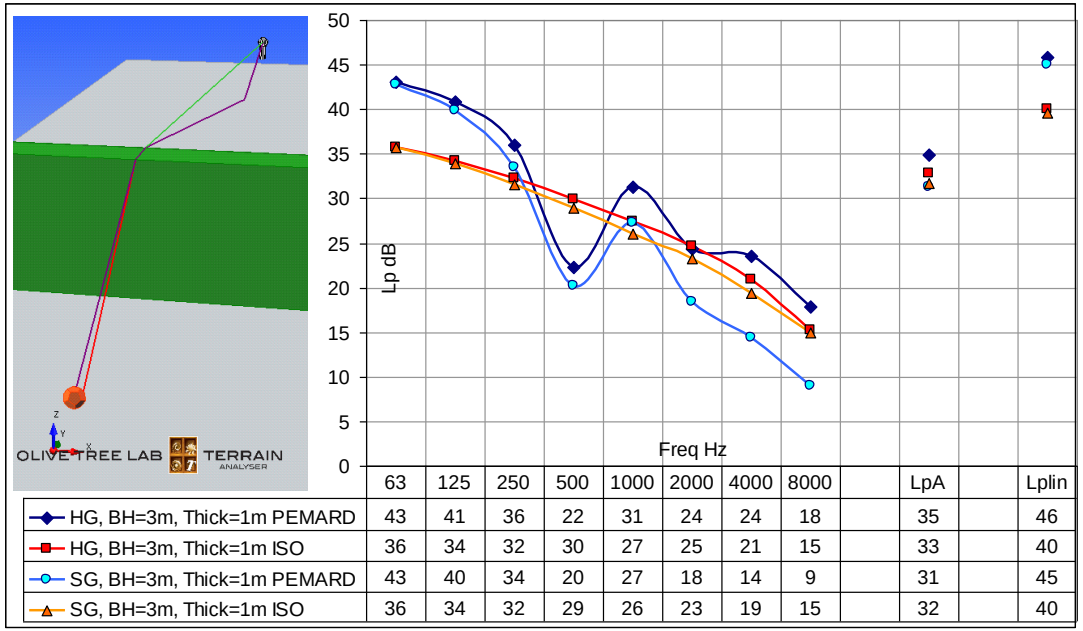
PART 2: PEMARD APPROACH

Isei's geometry, barrier height 3m, thin & wide, Hard vs Porous Ground



	63	125	250	500	1000	2000	4000	8000		LpA		Lplin
HG, BH=3m, Thin PEMARD	44	41	36	22	28	20	20	14		33		46
HG, BH=3m, Thin ISO	36	35	33	32	30	29	26	20		36		41
SG, BH=3m, Thin PEMARD	44	39	31	17	27	19	15	10		30		45
SG, BH=3m, Thin ISO	36	34	32	29	28	27	24	20		34		40

(a)



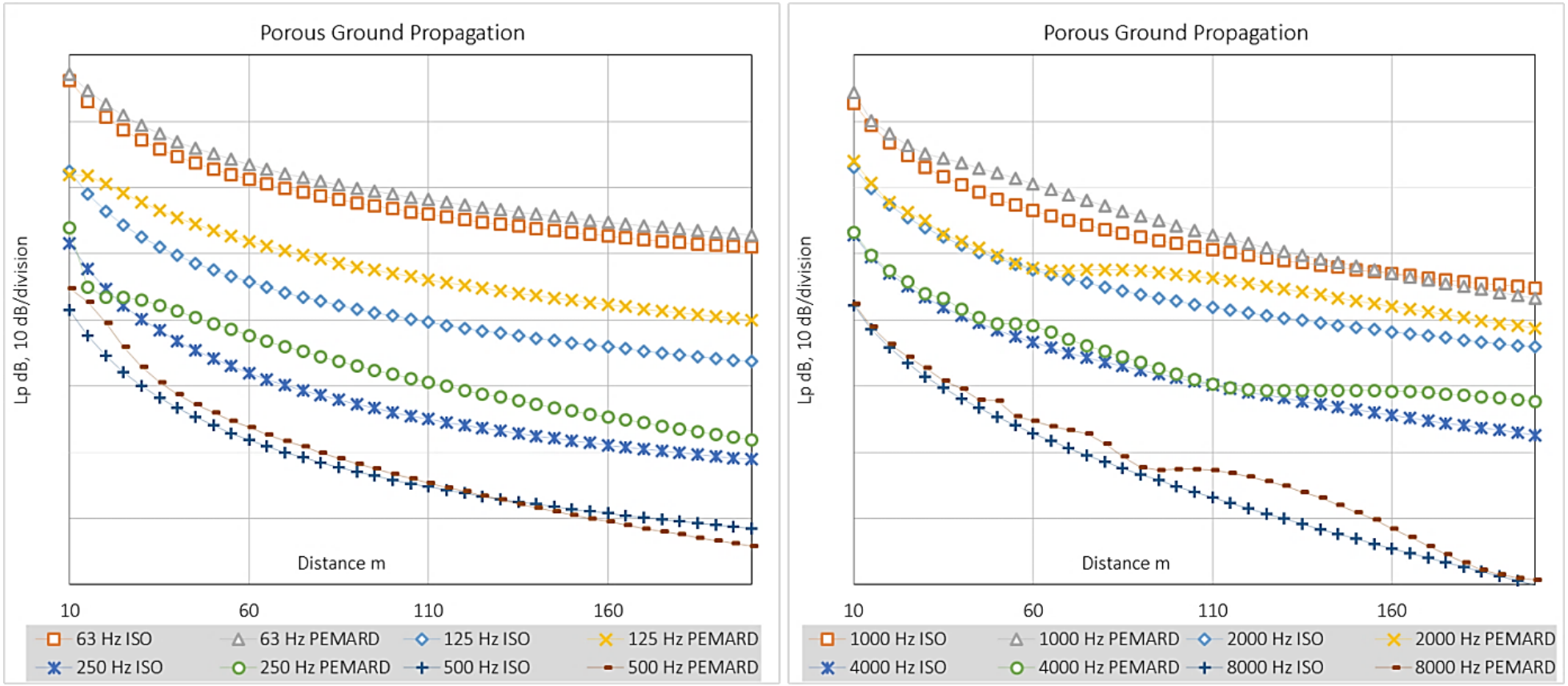
	63	125	250	500	1000	2000	4000	8000		LpA		Lplin
HG, BH=3m, Thick=1m PEMARD	43	41	36	22	31	24	24	18		35		46
HG, BH=3m, Thick=1m ISO	36	34	32	30	27	25	21	15		33		40
SG, BH=3m, Thick=1m PEMARD	43	40	34	20	27	18	14	9		31		45
SG, BH=3m, Thick=1m ISO	36	34	32	29	26	23	19	15		32		40

(b)

Figure 1: SPL spectra, L_{pA} and L_p values based on Isei's geometry, HG=GFR=20 MNs/m^4, PG (SG)=GFR=300 kNs/m^4 (a) Hs=0.3m, Hr=1.2m, Hb=3.0m, Dsr=35m, (b) Hs=0.3m, Hr=1.2m, Hb=1.5m, 1m thick barrier, Dsr=35m.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

PART 2: PEMARD APPROACH

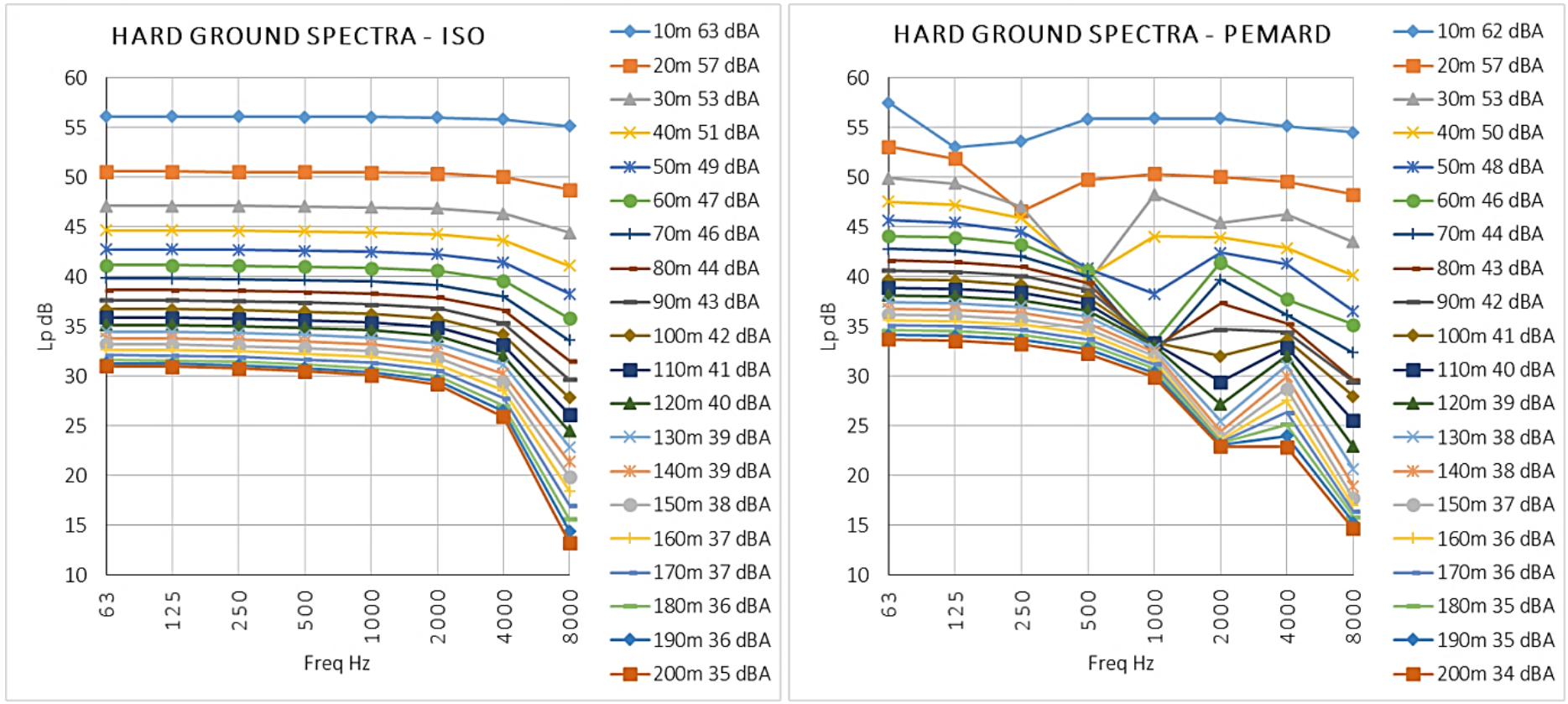


(a) (b)

Figure 1: Sound propagation over porous ground in relative levels (10 dB/division), (a) in octave bands between 63 and 500 Hz and (b) from 1000 and 8000 Hz. HG=GFR= 20 MNs/m^4, and PG=GFR=300 kNs/m^4, with Hs=5m and receivers at Hr=1m every 10m from the source up to 200m.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

PART 2: PEMARD APPROACH

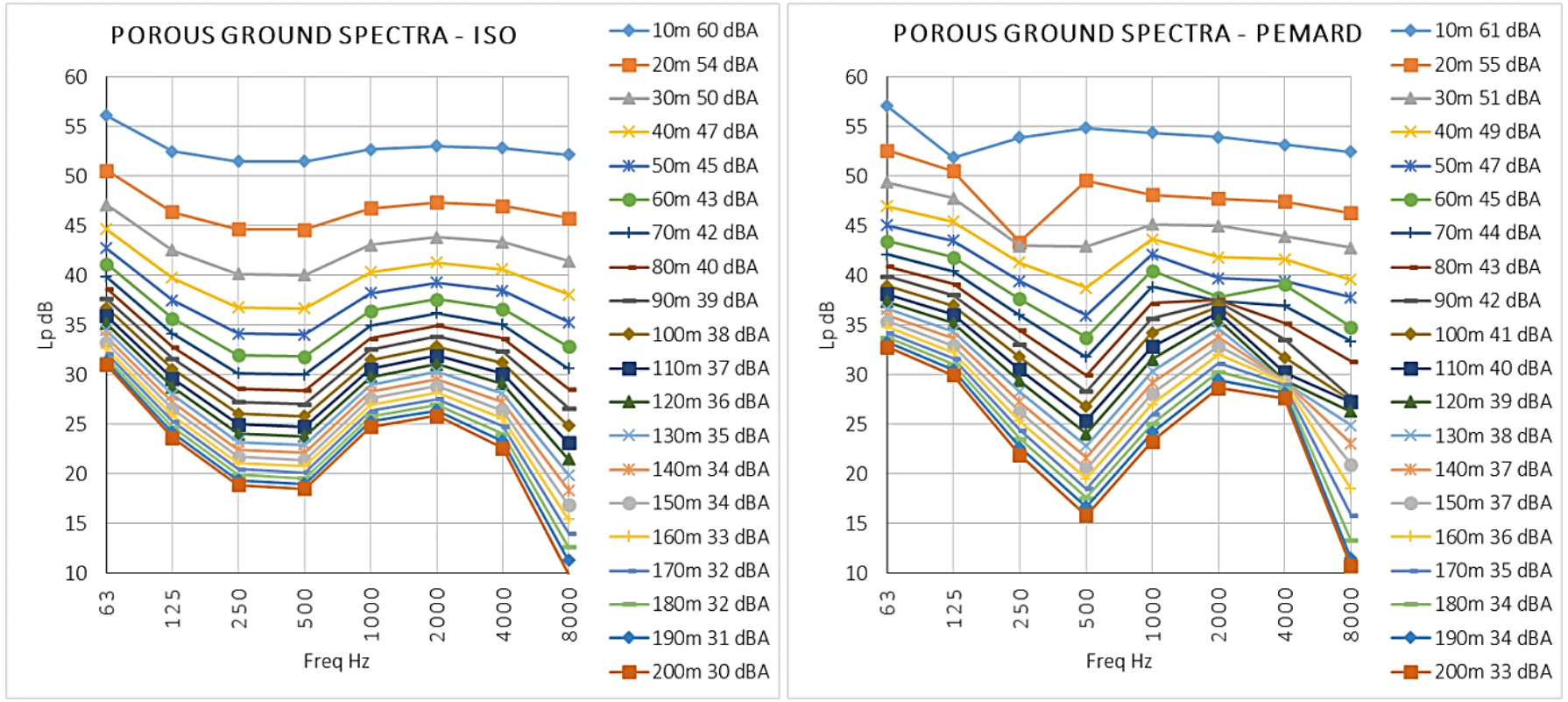


(a) (b)

Figure 1: Sound spectra at various distances from the source over hard ground. The legend includes dB(A) values at each distance from the source, (a) ISO results, (b) PEMARD results. HG=GFR= 20 MNs/m^4, and PG=GFR=300 kNs/m^4, with Hs=5m and receivers at Hr=1m every 10m from the source up to 200m.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

PART 2: PEMARD APPROACH

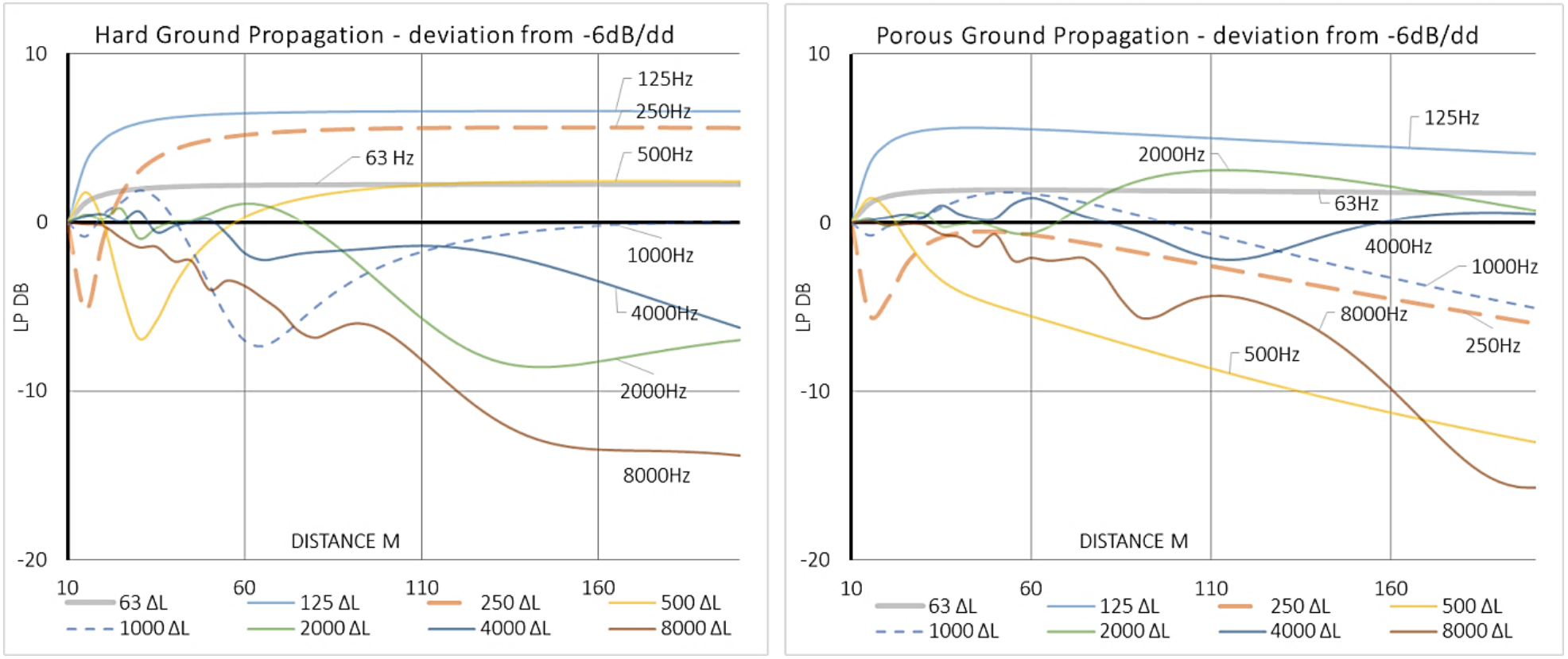


(a) (b)

Figure 1: Sound spectra at various distances from the source over porous ground. The legend includes dB(A) values at each distance from the source, (a) ISO results, (b) PEMARD results. HG=GFR= 20 MNs/m^4, and PG=GFR=300 kNs/m^4, with Hs=5m and receivers at Hr=1m every 10m from the source up to 200m.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

PART 2: PEMARD APPROACH



(a) (b)

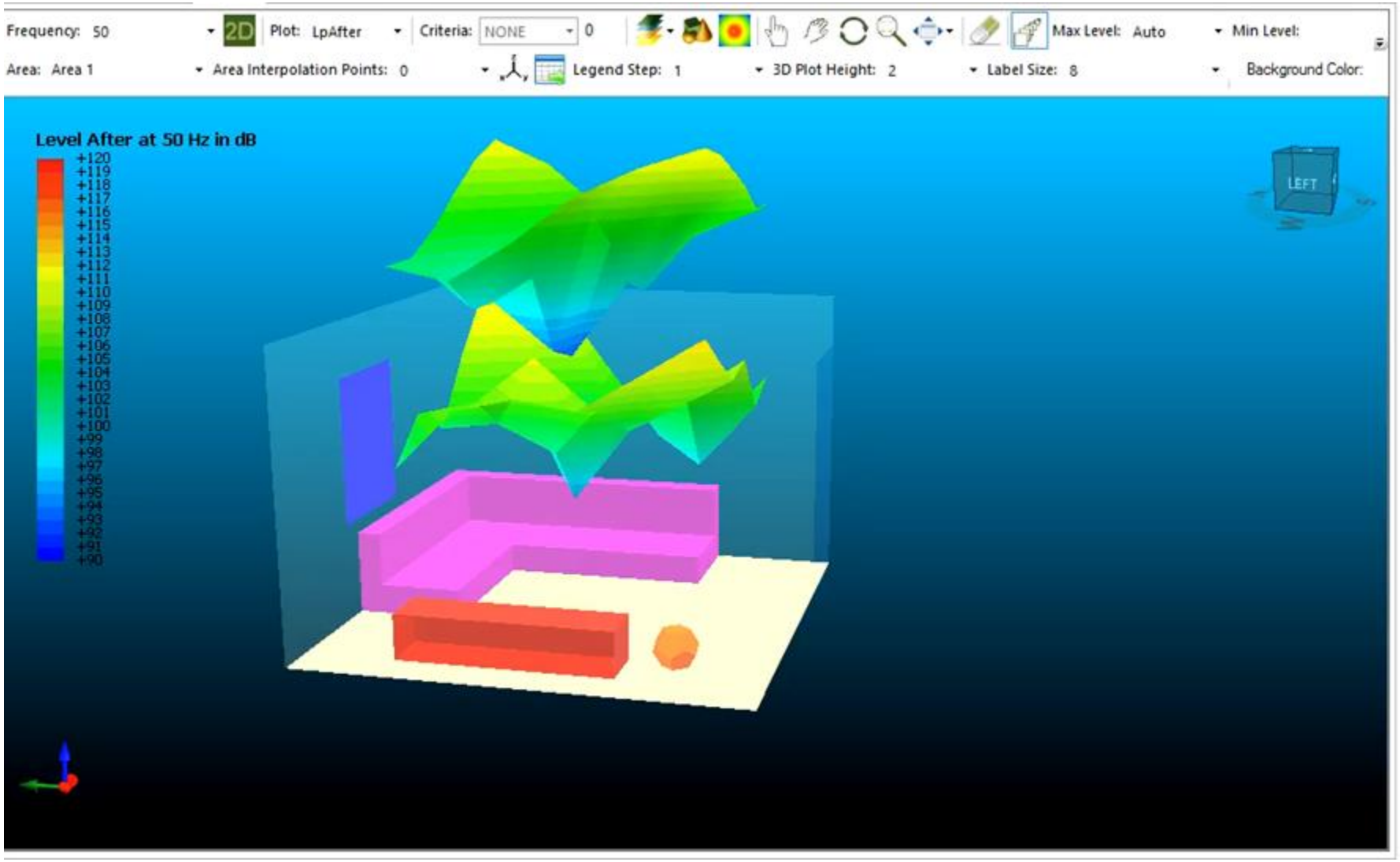
Figure 1: PEMARD results demonstrate how the -6dB/dd rule does not apply over finite impedance ground, (a) over hard ground, (b) over porous ground. Any deviation from zero indicates that the rule does not apply.

ACCURACY OF WAVE BASED CALCULATION METHODS COMPARED TO ISO 9613-2, NOISE-CON, ECONOMOU ET AL, SEPT 2014

PART 2: PEMARD APPROACH

ROOM RESONANCES

PART 2: PEMARD APPROACH



Upper mapping: Calculated results

Lower mapping: Measured results

USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA) TO INVESTIGATE ROOM RESONANCES, JOHANSSON, ECONOMOU, BNAM, JUNE 2016

PART 2: PEMARD APPROACH

OCTOBER, 1939 J. A. S. A. VOLUME 11

Normal Modes of Vibration in Room Acoustics: Experimental Investigations in Nonrectangular Enclosures*

RICHARD H. BOLT**
University of California at Los Angeles, California

(Received August 17, 1939)

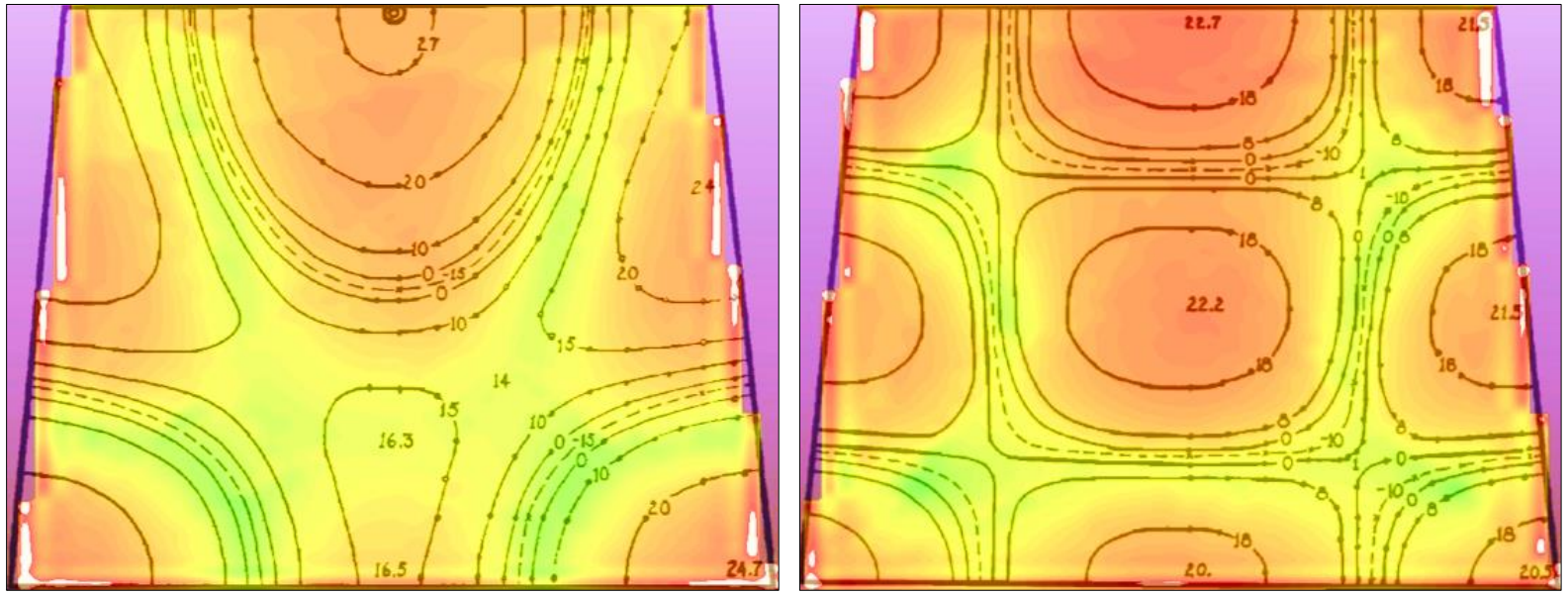


Figure 1: Mapping on the left is at 1721 Hz (higher by a scale factor of 10, experimental data, courtesy of the JASA) while the coloured mapping in the 1/3rd octave band of 200 Hz. The mapping on the right is at 2302 Hz (higher by a scale factor of 10, experimental data) while the coloured mapping in the 1/3rd octave band of 250 Hz. In red high sound levels and in green low [5].

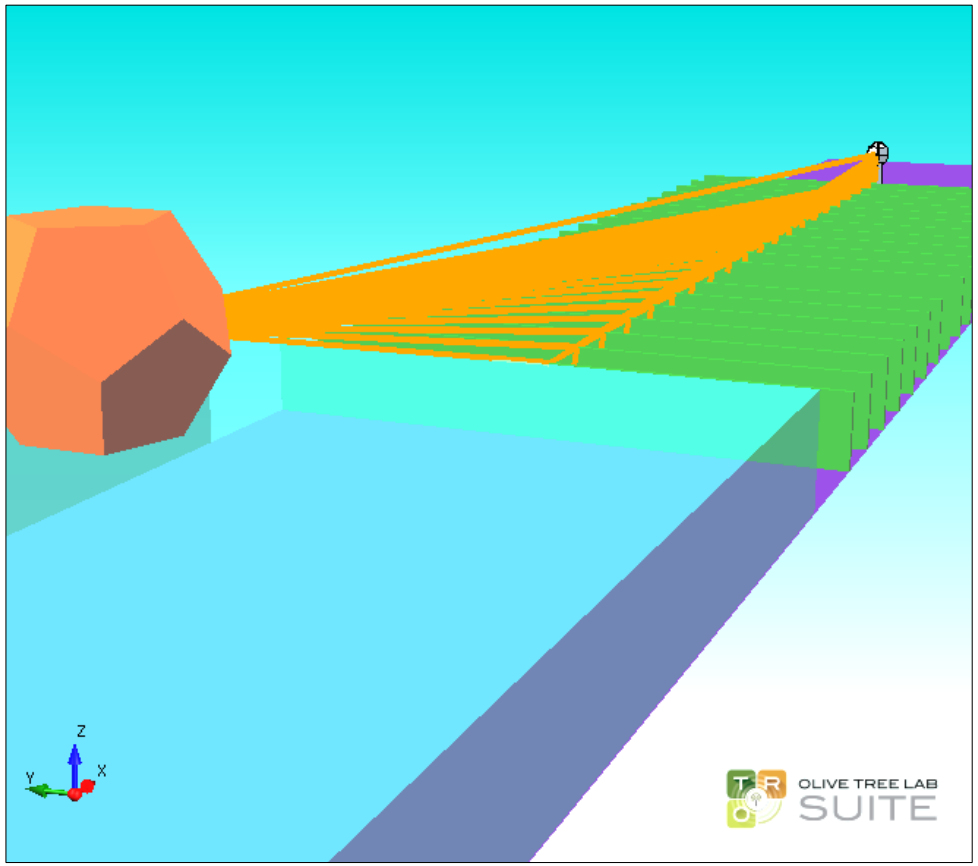
ROOM RESONANCES USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 2: PEMARD APPROACH

DIFFRACTION EFFECTS

PART 2: PEMARD APPROACH

PART 2: PEMARD APPROACH



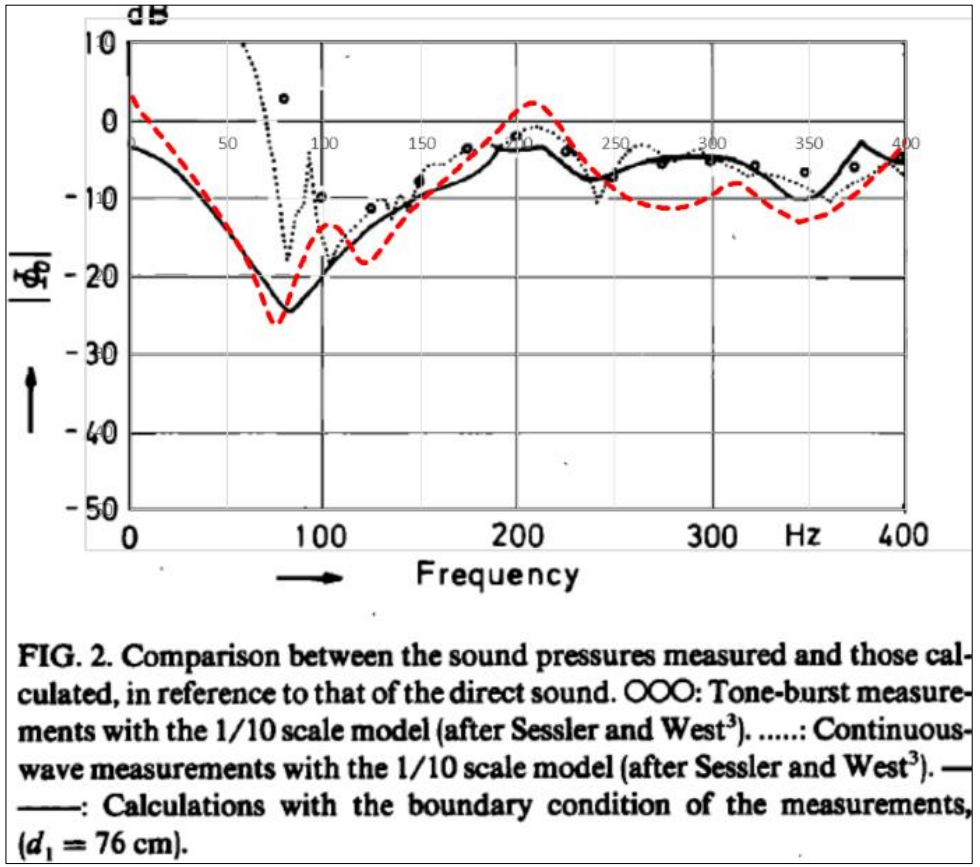
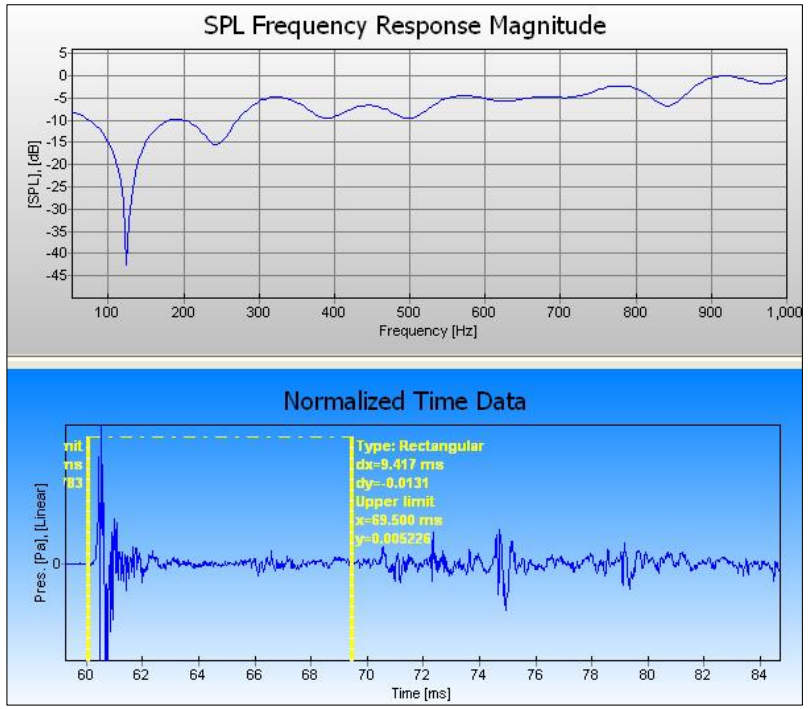


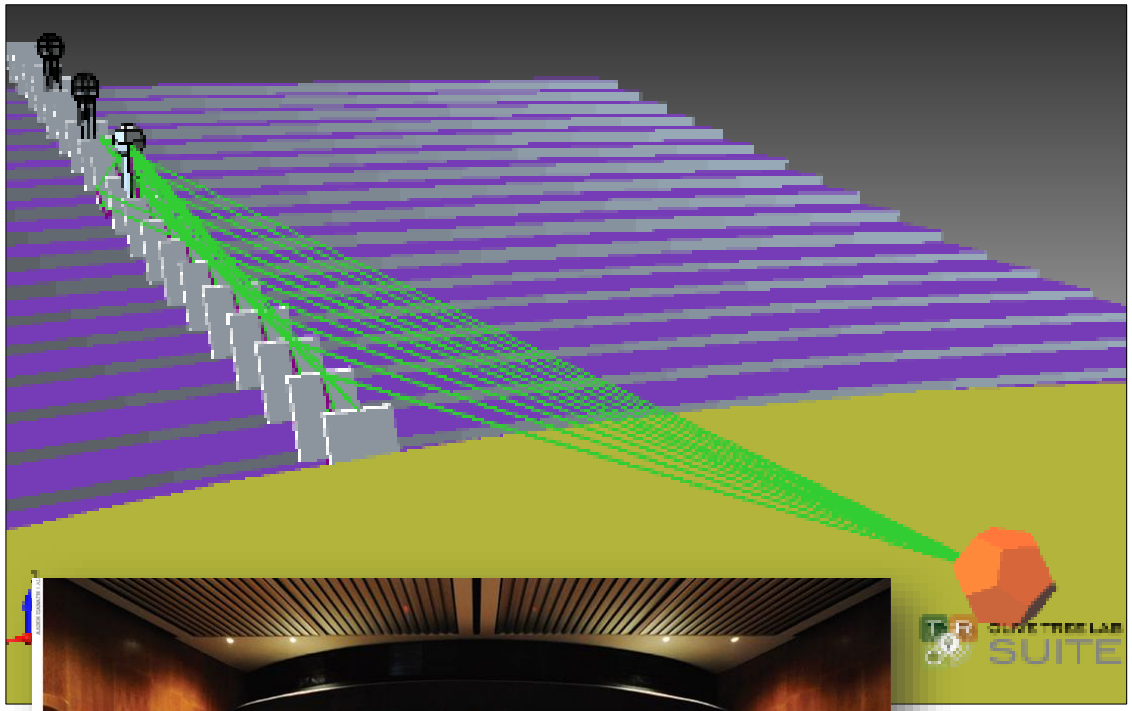
FIG. 2. Comparison between the sound pressures measured and those calculated, in reference to that of the direct sound. OOO: Tone-burst measurements with the 1/10 scale model (after Sessler and West[3]). .....: Continuous-wave measurements with the 1/10 scale model (after Sessler and West[3]). ——: Calculations with the boundary condition of the measurements, ($d_1 = 76$ cm).

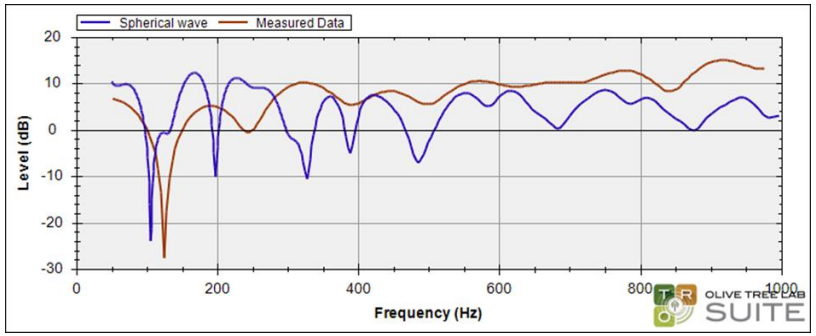
Figure 1: On the left, the 3D full scale model used for our calculations. On the right Ando's results compared to experimental data. Our calculations are superimposed as a red curve over the original graph by Ando (courtesy of the Journal of the Acoustical Society of America).

THE SEAT DIP EFFECT USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

PART 2: PEMARD APPROACH

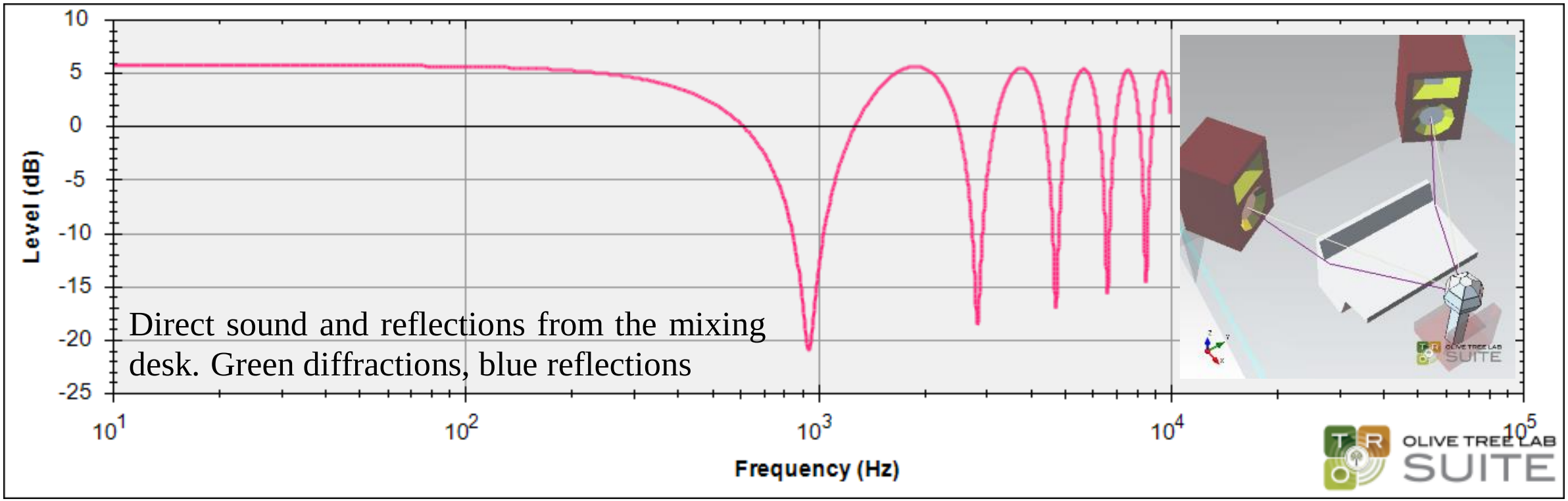






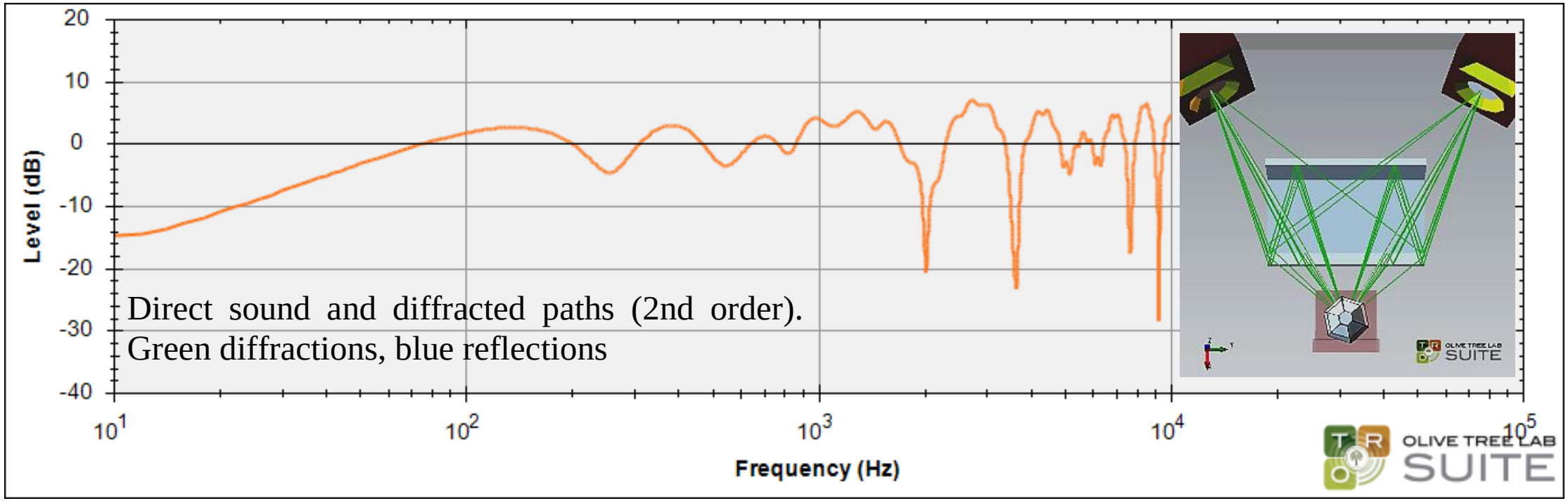
THE SEAT DIP EFFECT USING WAVE BASED GEOMETRICAL ACOUSTICS (WBGA), ECONOMOU ET AL, ICSV23, JULY 2016

APPLICATIONS OF WBGA
SOUND REFLECTIONS OFF A MIXING CONSOLE



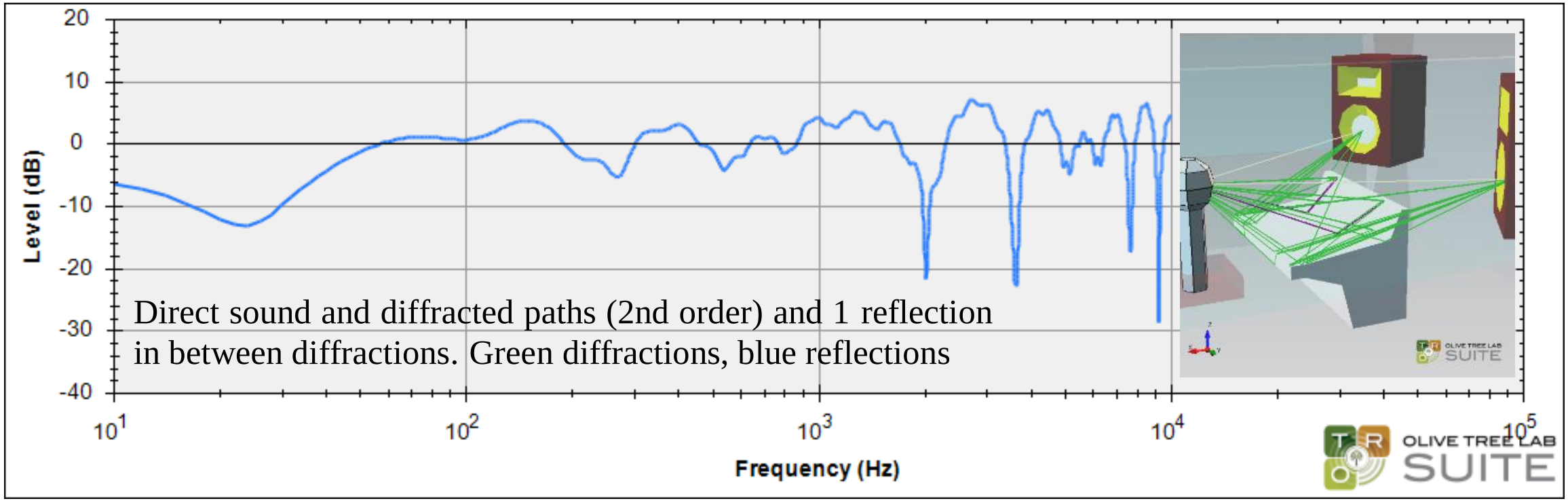
IMPROVED ROOM ACOUSTICS CALCULATIONS USING COMPLEX IMPEDANCE AND SPHERICAL WAVE REFLECTION & DIFFRACTION COEFFICIENTS, ECONOMOU ET AL, ICSV23, JULY 2016

APPLICATIONS OF WBGA
SOUND DIFFRACTIONS OFF A MIXING CONSOLE



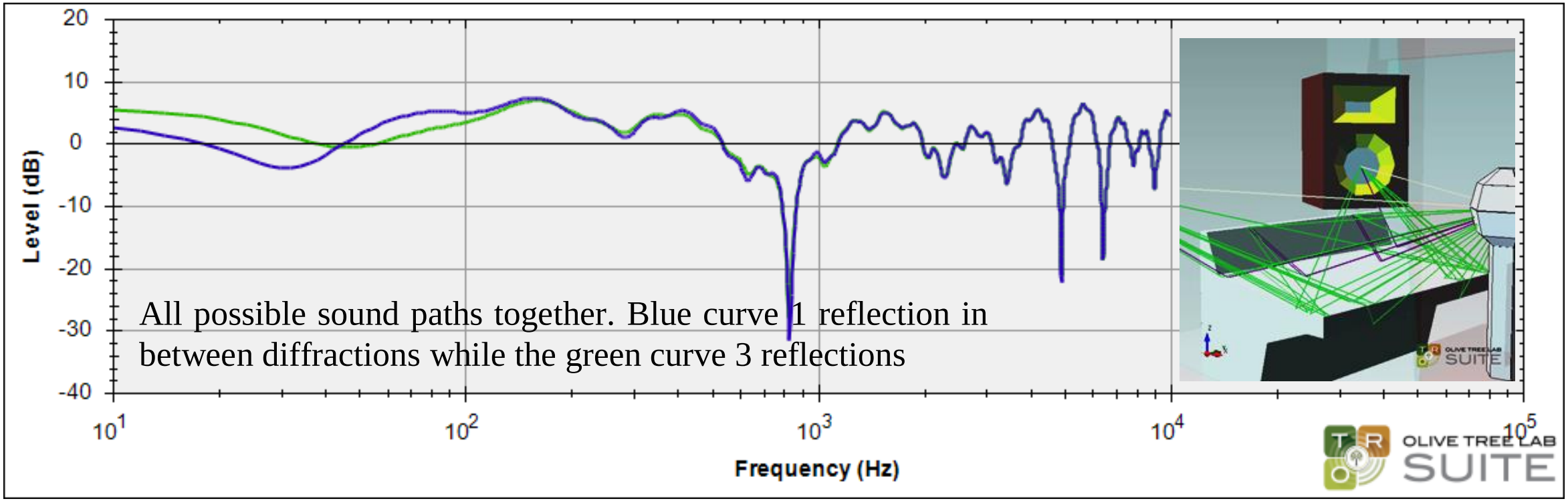
IMPROVED ROOM ACOUSTICS CALCULATIONS USING COMPLEX IMPEDANCE AND SPHERICAL WAVE REFLECTION & DIFFRACTION COEFFICIENTS, ECONOMOU ET AL, ICSV23, JULY 2016

APPLICATIONS OF WBGA
SOUND DIFFRACTIONS WITH IN BETWEEN REFLECTIONS OFF A MIXING CONSOLE



IMPROVED ROOM ACOUSTICS CALCULATIONS USING COMPLEX IMPEDANCE AND SPHERICAL WAVE REFLECTION & DIFFRACTION COEFFICIENTS, ECONOMOU ET AL, ICSV23, JULY 2016

APPLICATIONS OF WBGA
SOUND REFLECTIONS & DIFFRACTIONS (ALL) OFF A MIXING CONSOLE



IMPROVED ROOM ACOUSTICS CALCULATIONS USING COMPLEX IMPEDANCE AND SPHERICAL WAVE REFLECTION & DIFFRACTION COEFFICIENTS, ECONOMOU ET AL, ICSV23, JULY 2016

PART 2: PEMARD APPROACH

STUDYING THE PHENOMENON - REVERBERATION

PART 2: PEMARD APPROACH

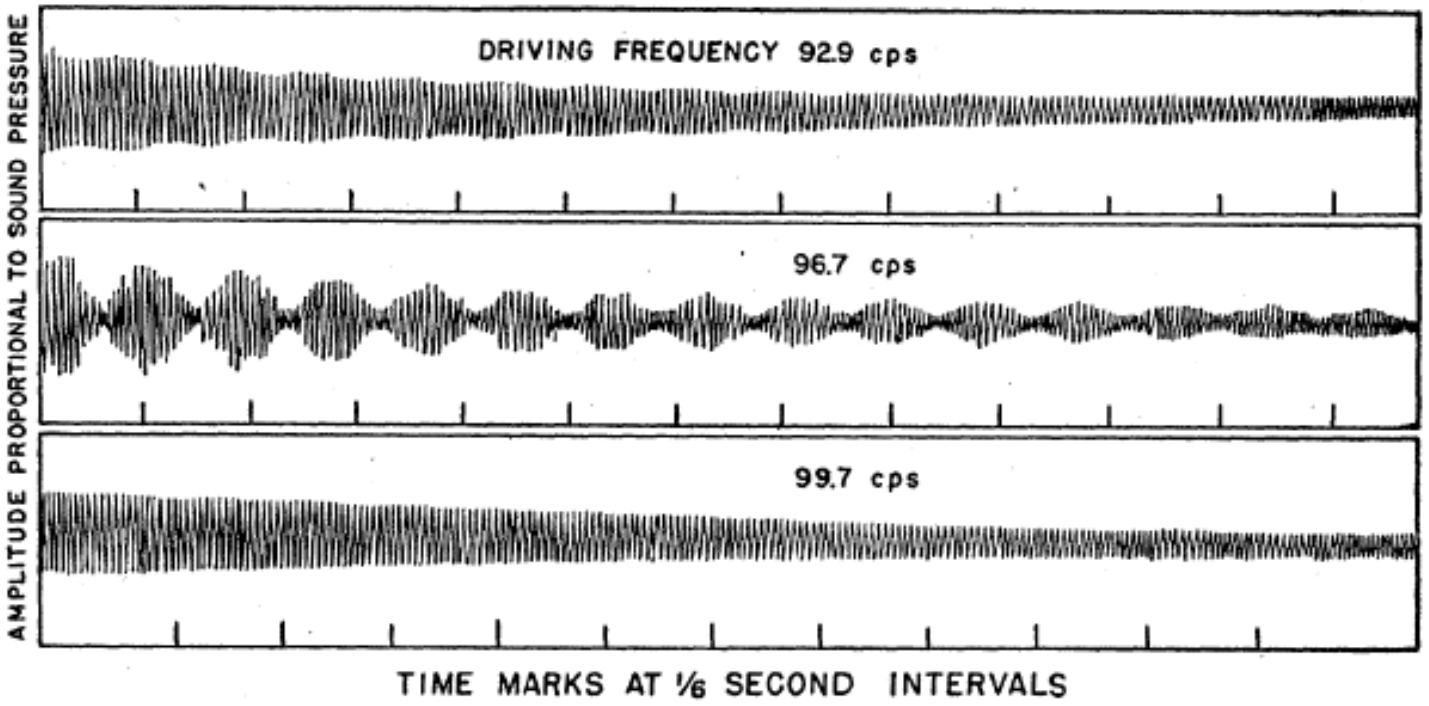


FIG. 24. Oscillograms illustrating beats in sound decay for different driving frequencies. Top and bottom curves are for driving frequency equal to a resonance frequency of the room, so only one mode is strongly excited. Middle curve is for an intermediate driving frequency, with two modes equally excited, showing the beats between the two natural frequencies as they damp out. Redrawn from reference K5.

PART 2: PEMARD APPROACH

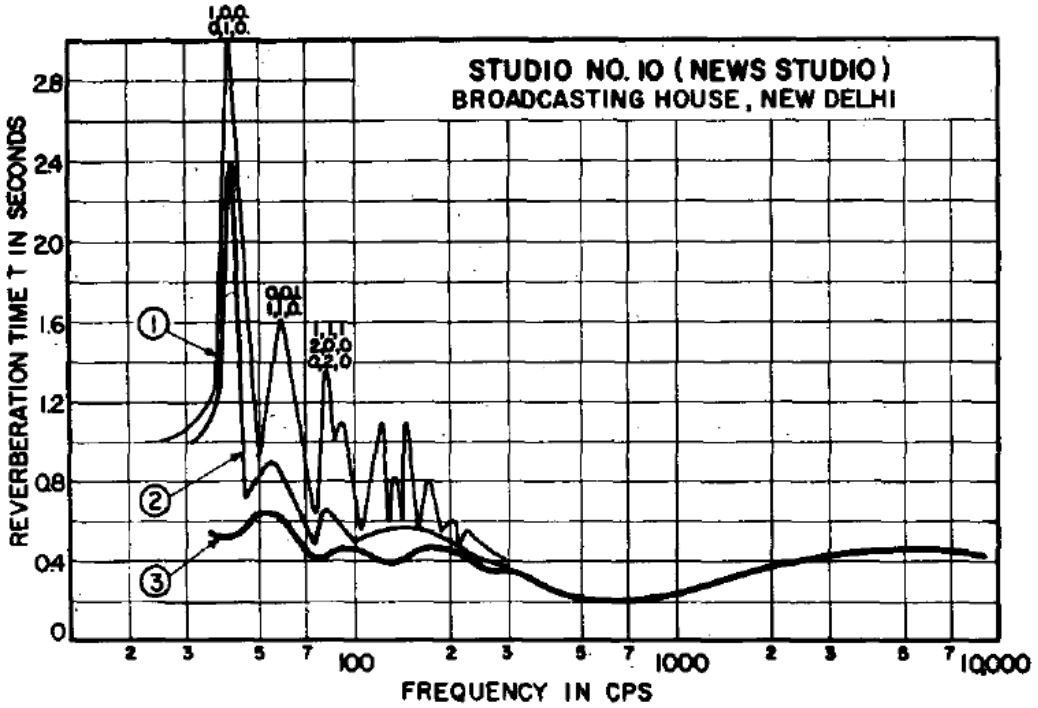


FIG. 1. "Reverberation Time" (?) of small broadcast studio.

"…… at the frequencies of the lowest resonant modes of the room, there is very little absorption by the walls and hence the reverberation time is high; whereas at frequencies only a few cycles away from the resonance there is a much shorter reverberation time and, therefore, the walls must be much more absorptive. Presumably if the room were a different size, the absorption dips (hence, reverberation peaks) exhibited by the walls would occur at different frequencies corresponding to the new modes of the room. **One can hardly believe that the ordinary rigid, bare walls of a room could show such wide (and variable!) differences in absorption within such a narrow frequency range. What, then, is the trouble with these curves? Surprisingly, there appear to be at least three methods of measurement which would give this kind of wrong answer!" (**Courtesy of JAES, from Theodore Schultz's paper "Problems in Measurement of Reverberation Time", *Journal of The Audio Engineering Society,* **11**(4), 307-317, (1963)**)**

PART 2: PEMARD APPROACH

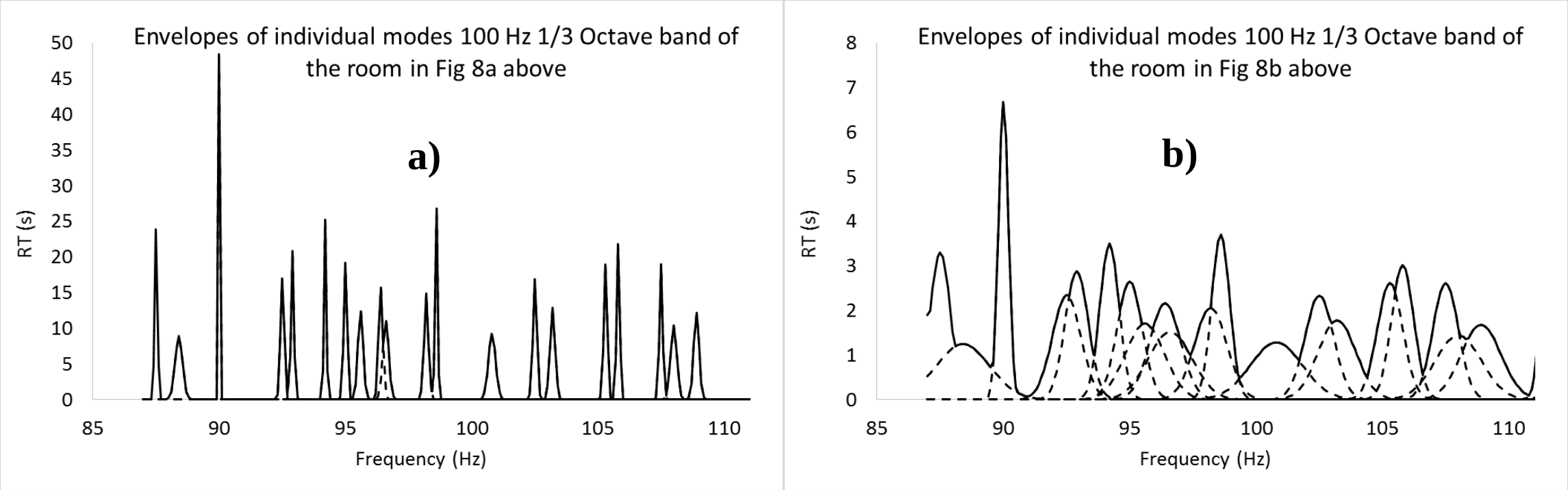


Figure 9: Detailed view of the 100 Hz 1/3 Octave Band frequency range (a) from Fig. 8a above and (b) from Fig. 8b. Spherical reflection factor was used for RT calculations. The dashed curves (-----) represent the RT curves for the individual resonance peaks while the solid curve shows the envelope of the superimposed resonance peaks.

BEYOND SABINE: INVESTIGATING THE ACOUSTICAL PHENOMENON OF REVERBERATION USING ROOM MODAL DECAY , UPCOMING ICSV24, ECONOMOU ET AL, JULY 2017

PART 2: PEMARD APPROACH

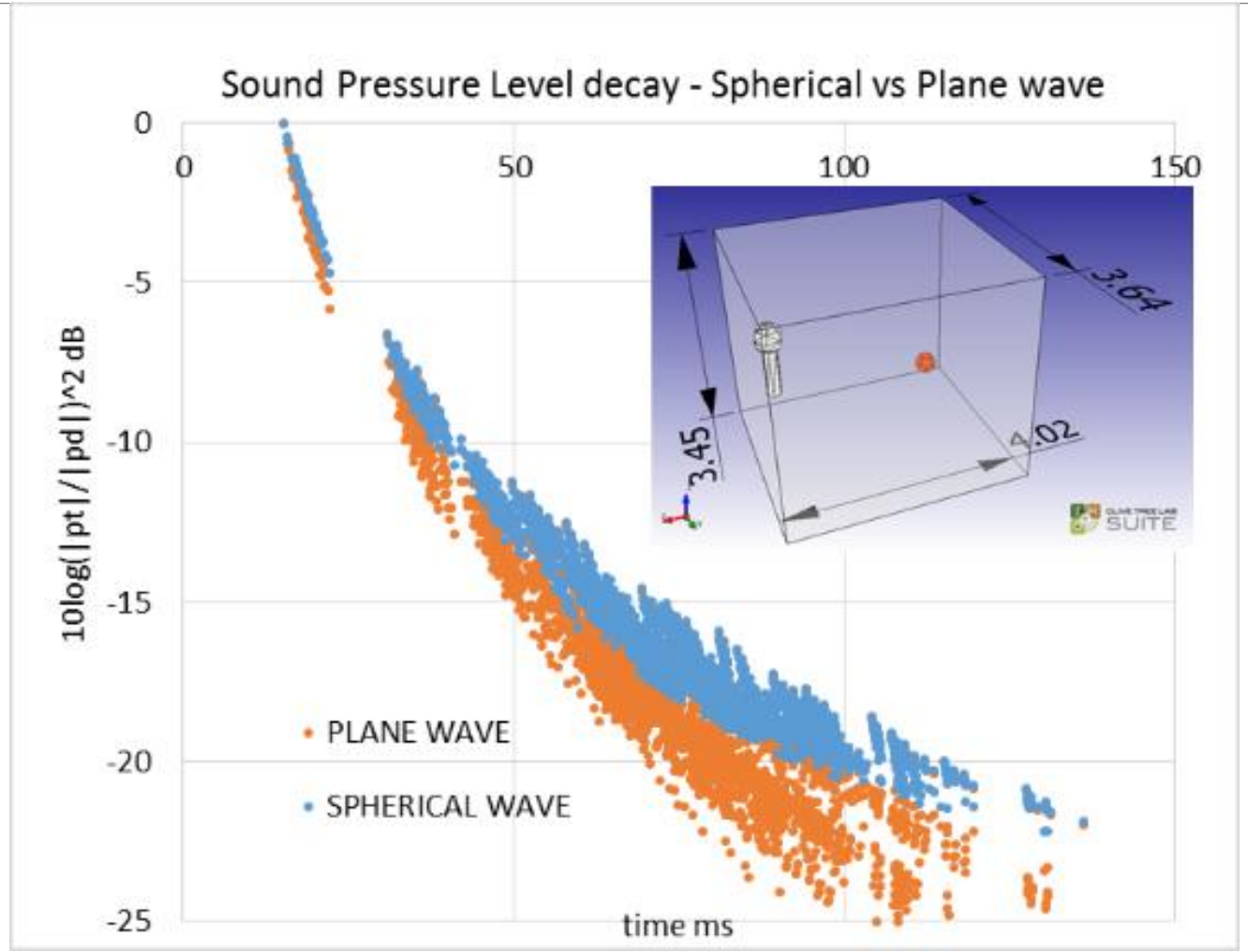
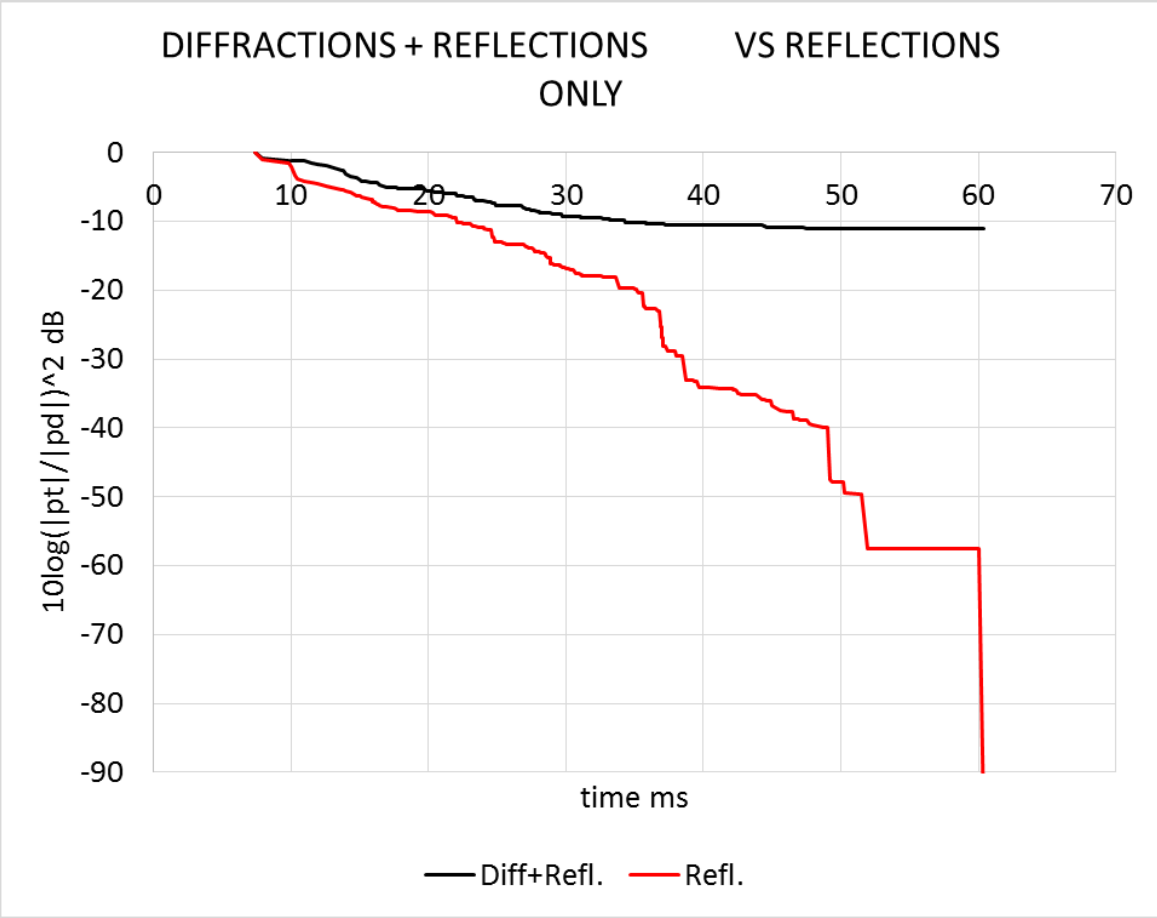


Figure 5: Sound decay in a small rectangular room. Plane vs spherical wave propagation.

BEYOND SABINE: INVESTIGATING THE ACOUSTICAL PHENOMENON OF REVERBERATION USING ROOM MODAL DECAY , UPCOMING ICSV24, ECONOMOU ET AL, JULY 2017

PART 2: PEMARD APPROACH



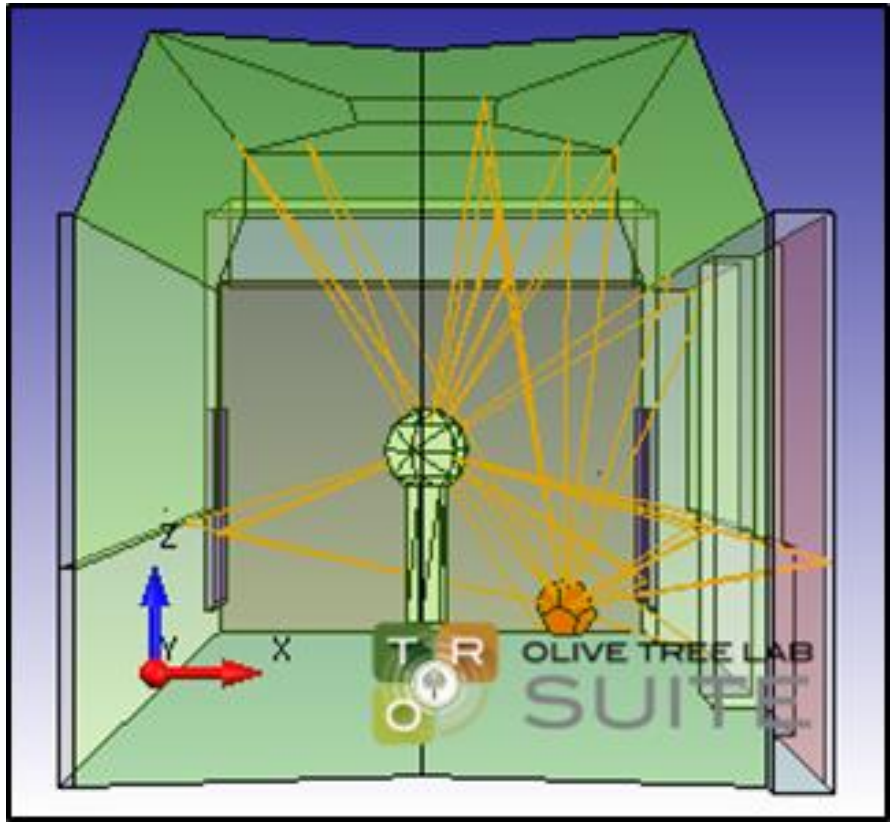


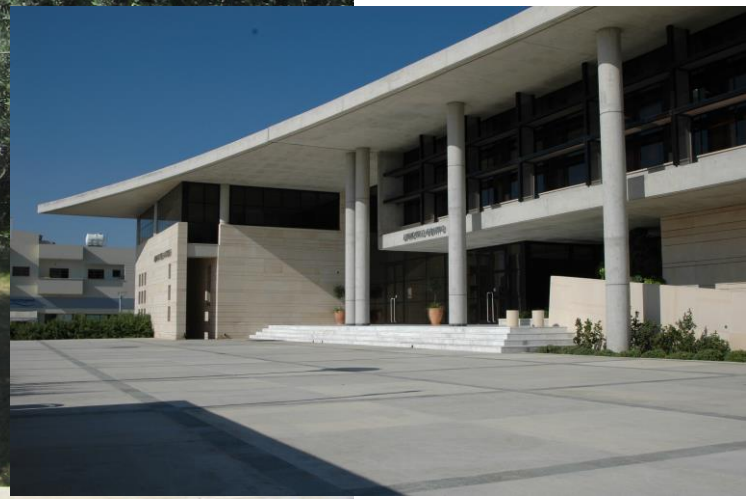
Figure 7: Sound decay with and without sound edge diffractions.

BEYOND SABINE: INVESTIGATING THE ACOUSTICAL PHENOMENON OF REVERBERATION USING ROOM MODAL DECAY , UPCOMING ICSV24, ECONOMOU ET AL, JULY 2017

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

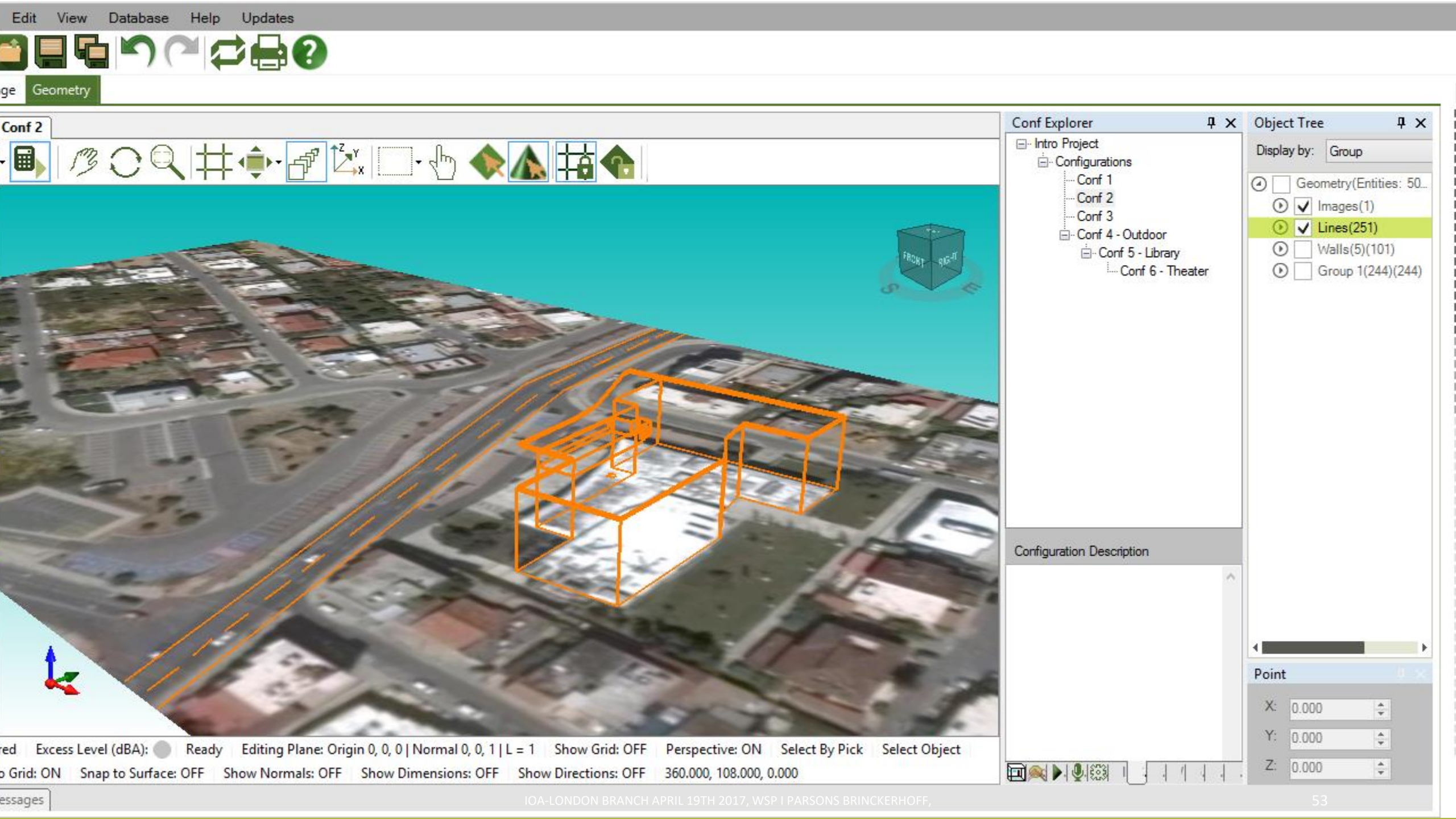
THE MUNICIPALITY BUILDING OF LATSIA – CYPRUS, AN EXAMPLE OF THE INTEGRATED APPROACH IN ACOUSTICS

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS



PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

MODELING


Edit
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Conf Explorer
Intro Project
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Conf 1
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Conf 3
Conf 4 - Outdoor
Conf 5 - Library
Conf 6 - Theater
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Images(1)
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Walls(5)(101)
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Perspective: ON
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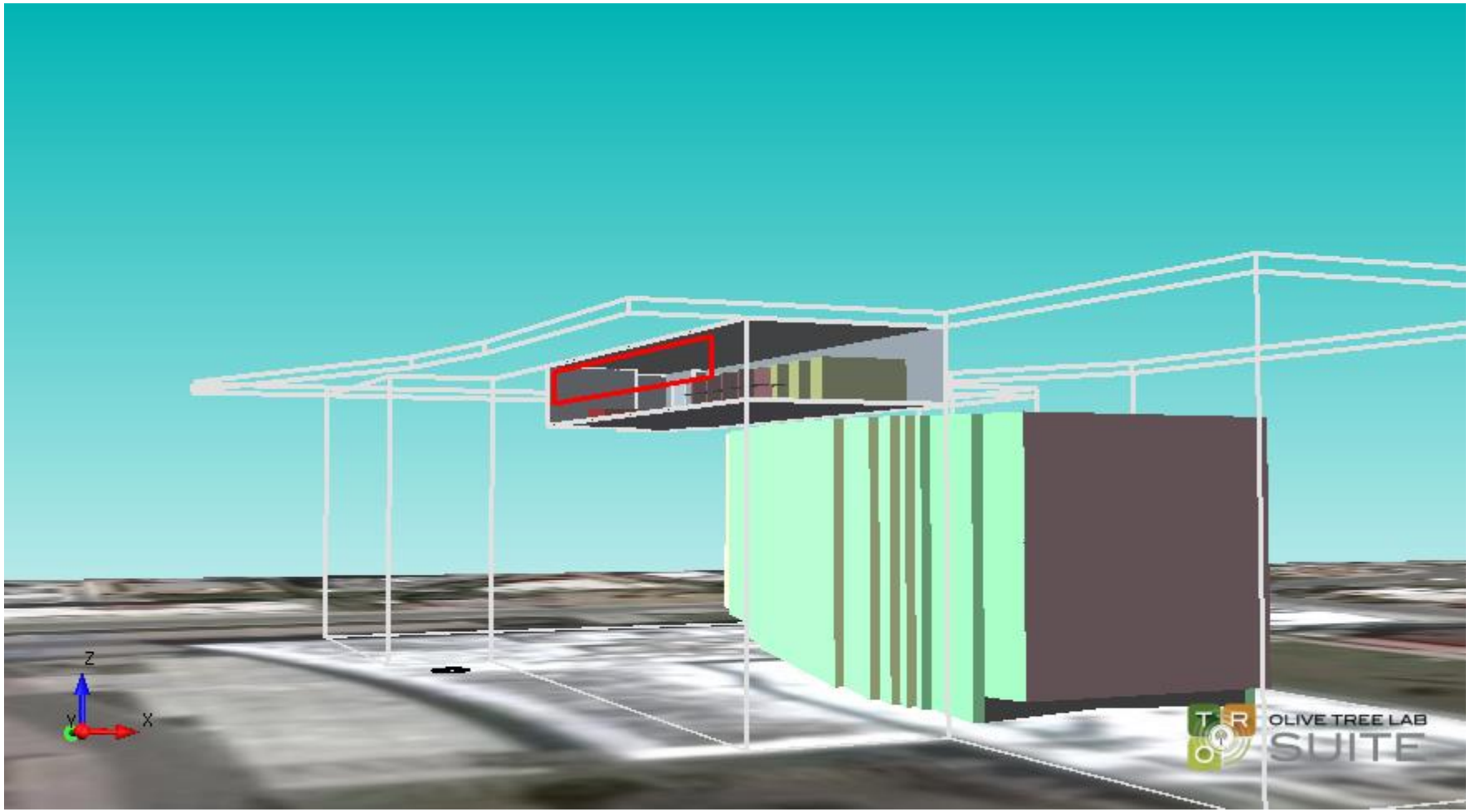
PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS



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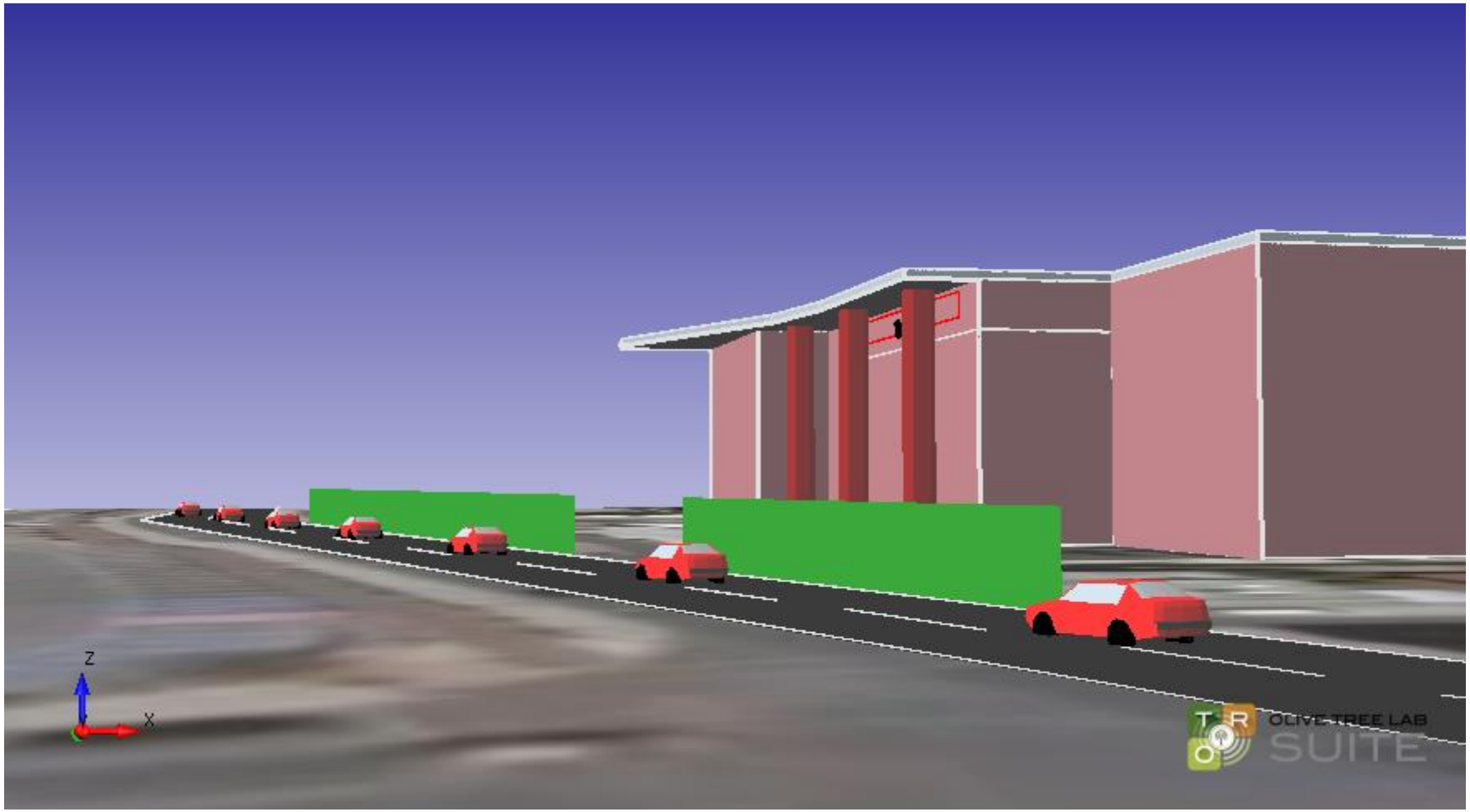
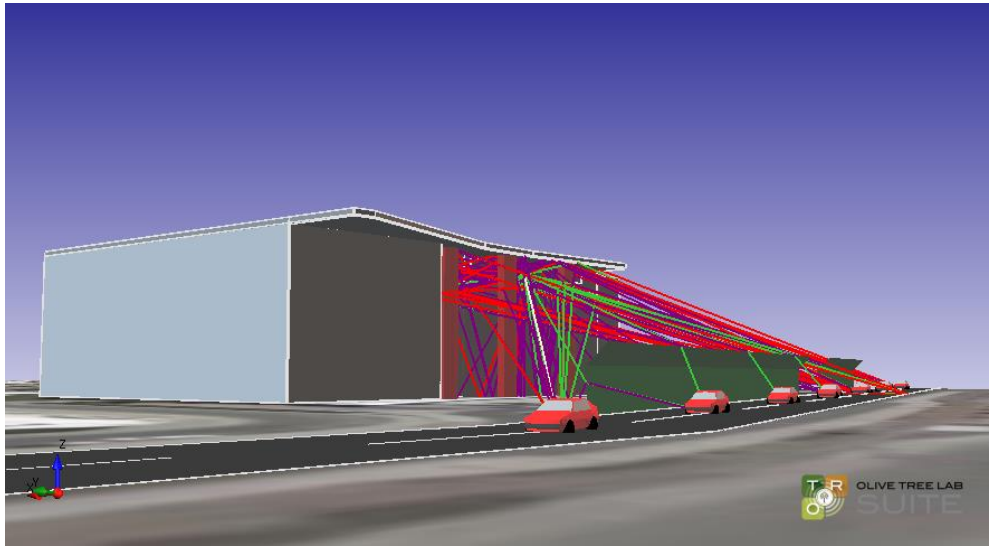
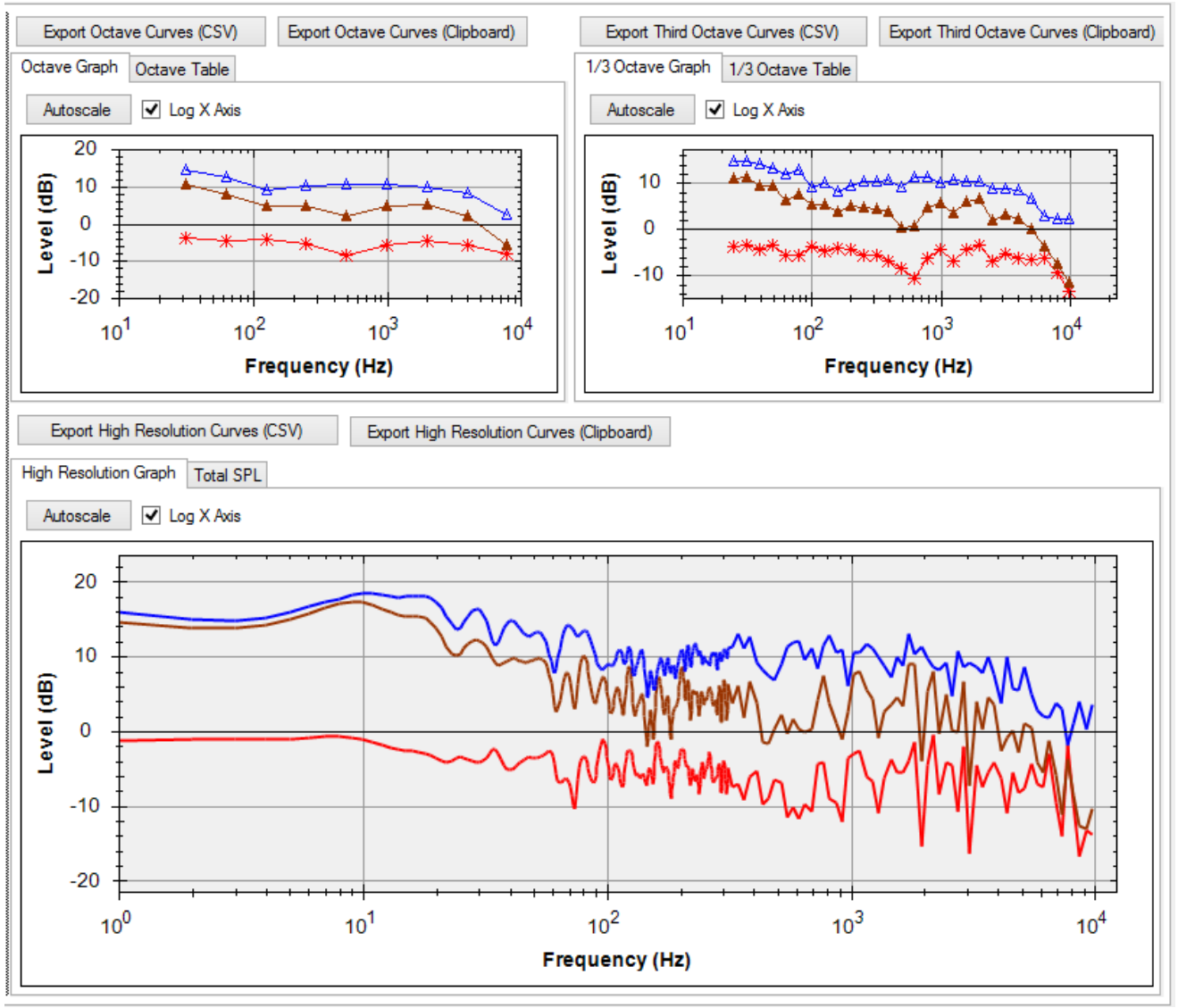


PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

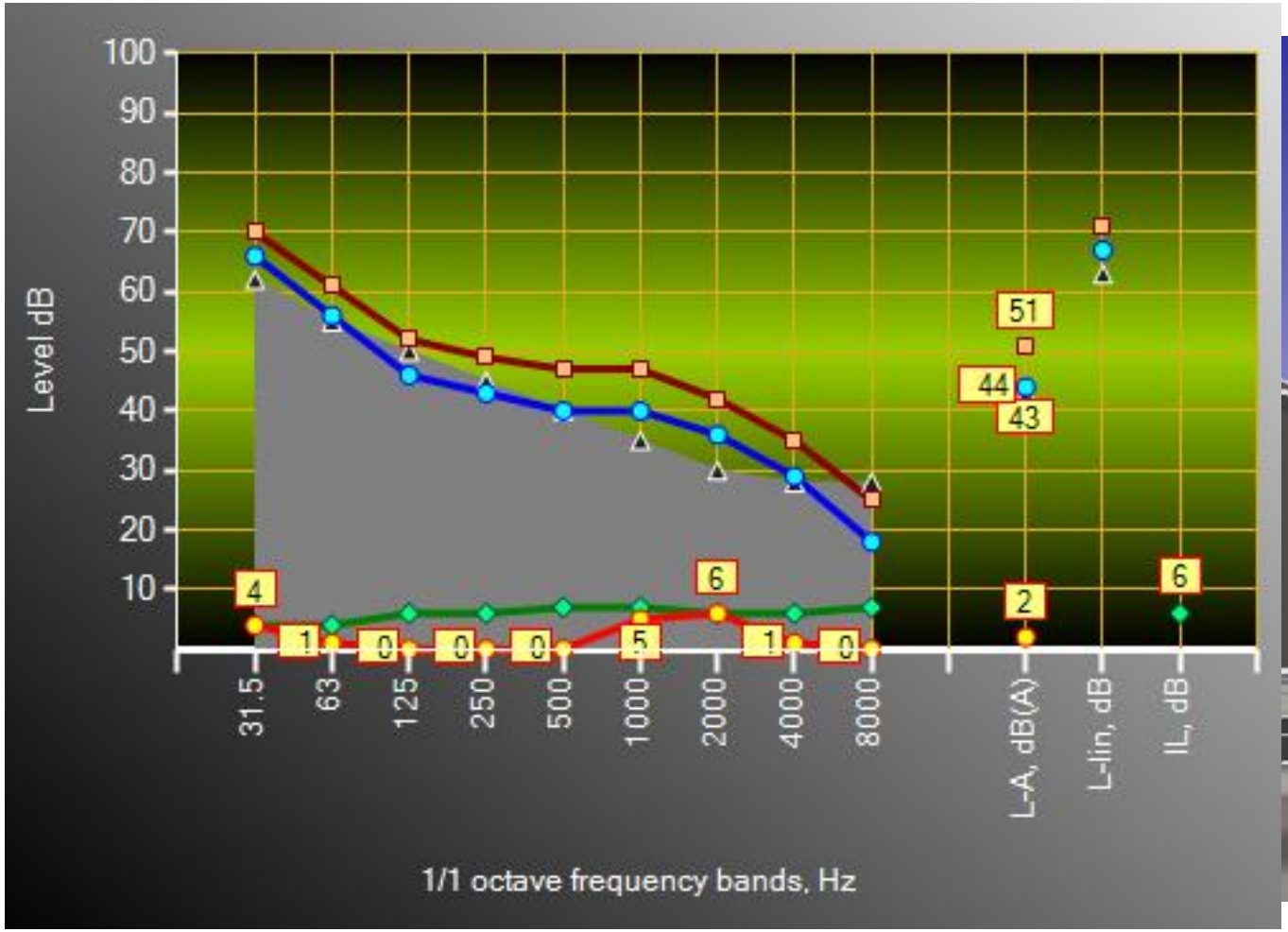
TRAFFIC NOISE AFFECTING LIBRARY GLAZING & THE EFFECT OF NOISE BARRIER

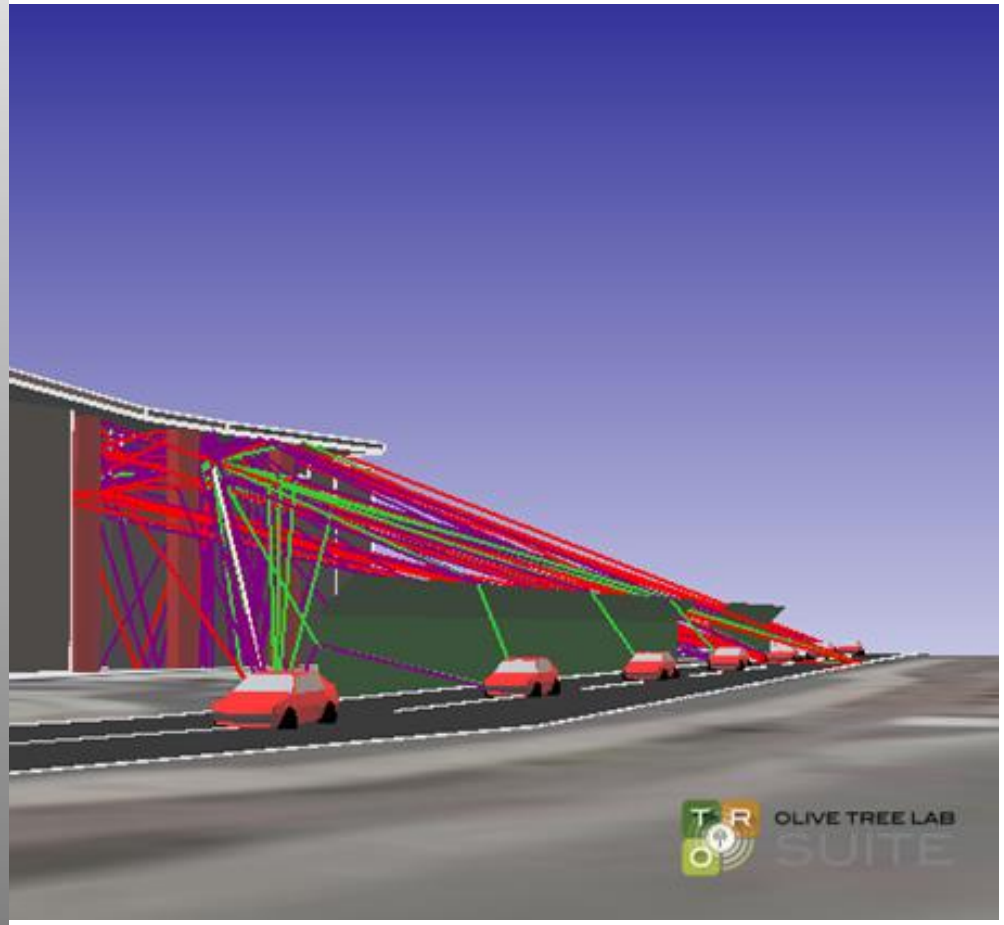
PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS





PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS





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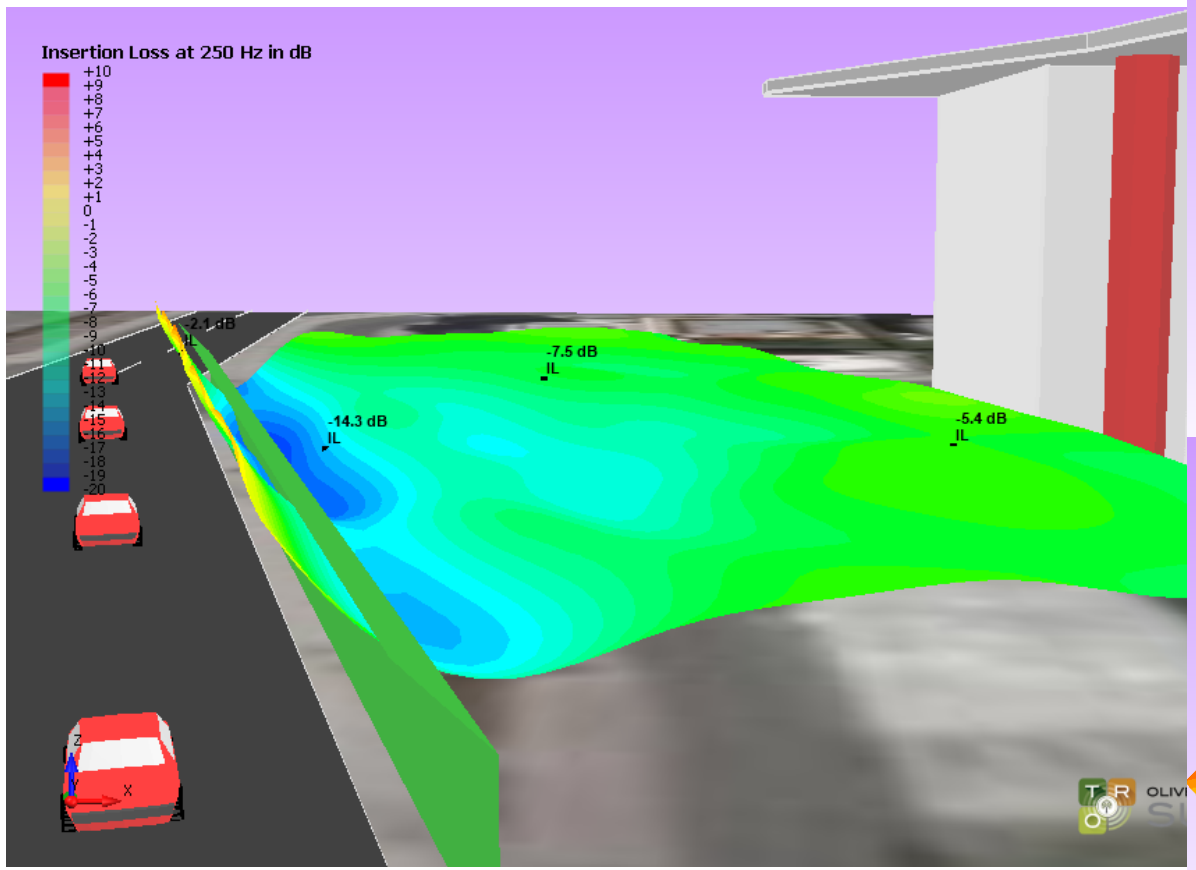
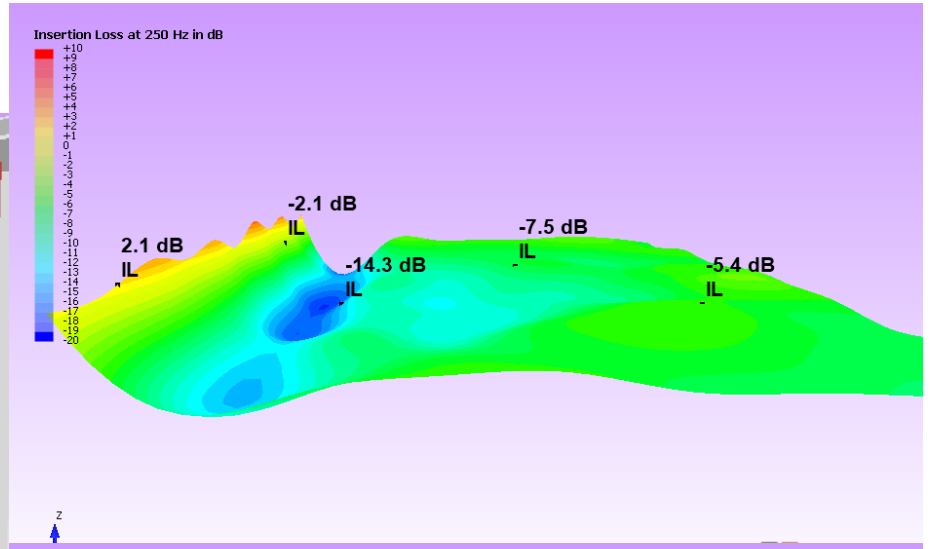
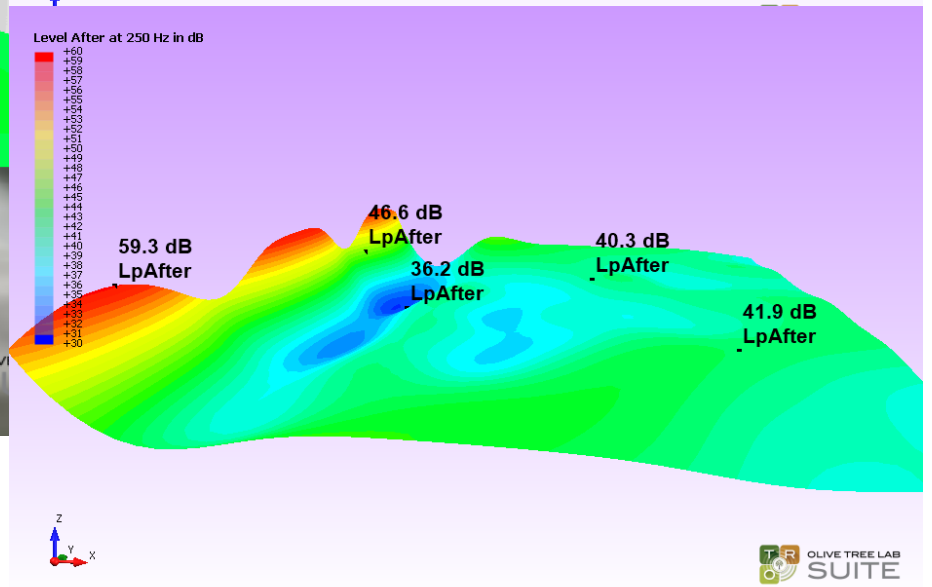


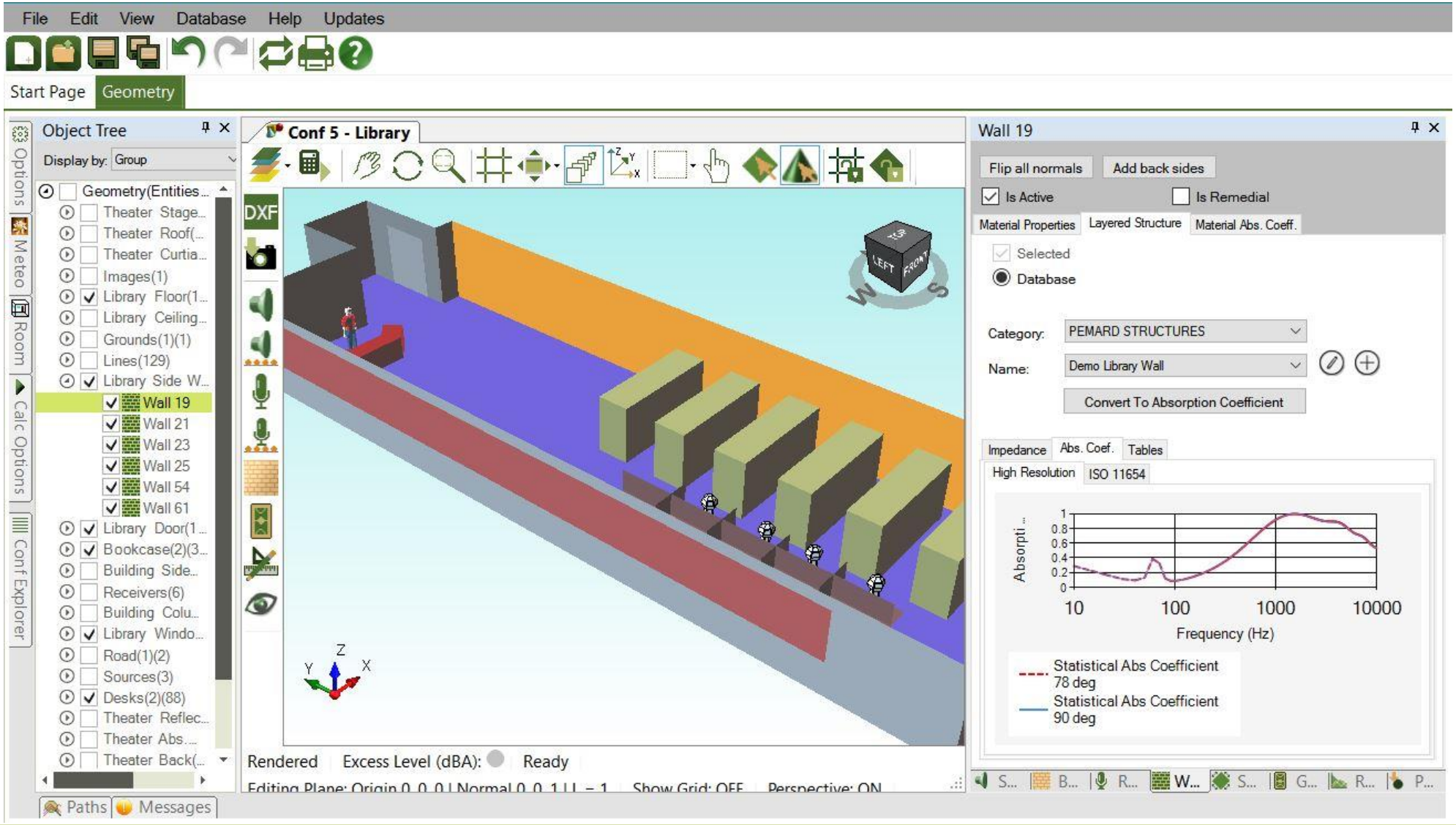




PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

DESIGNING THE LIBRARY WALL USING THE TRANSFER MATRIX METHOD (TMM)

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS



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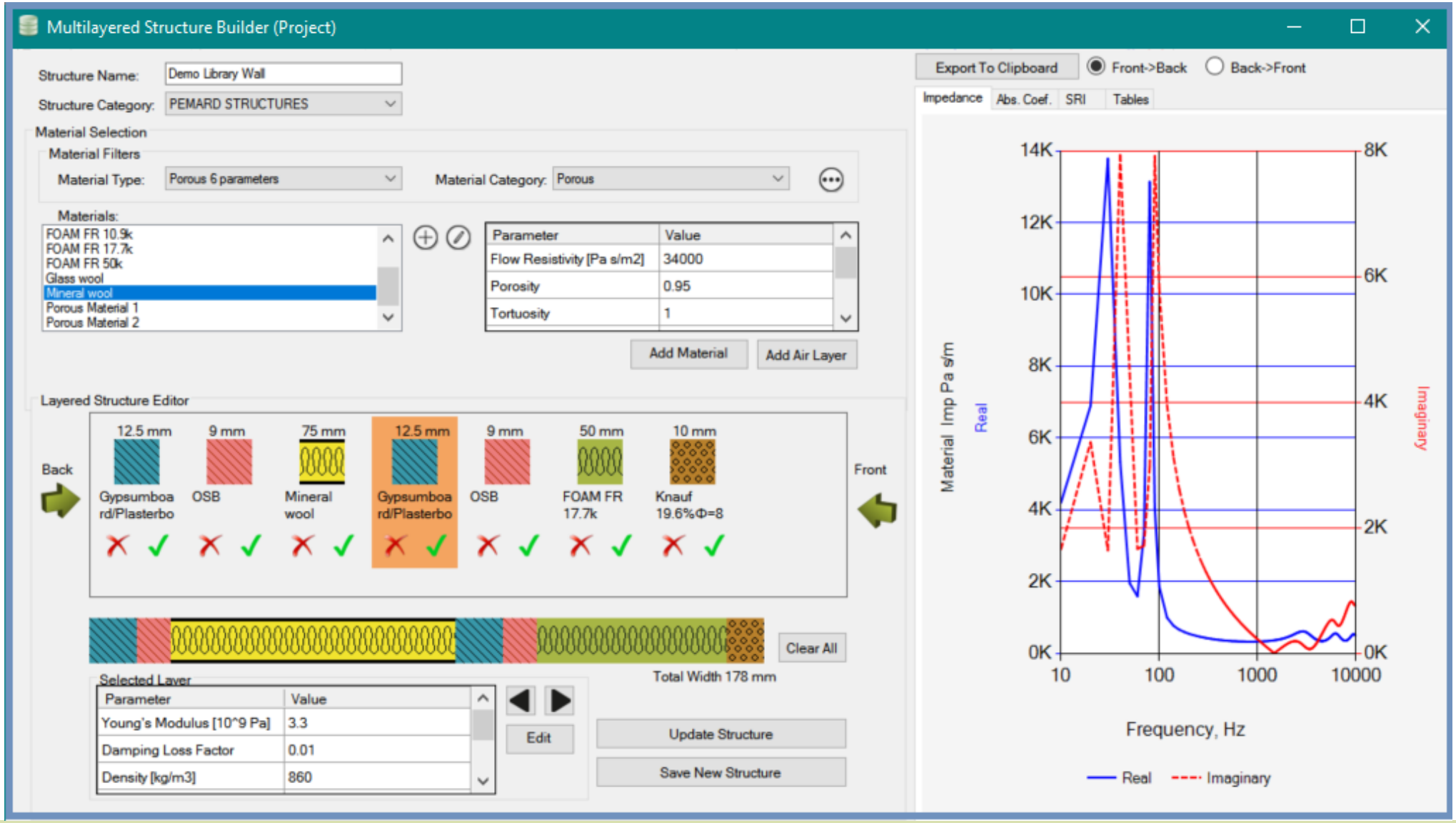

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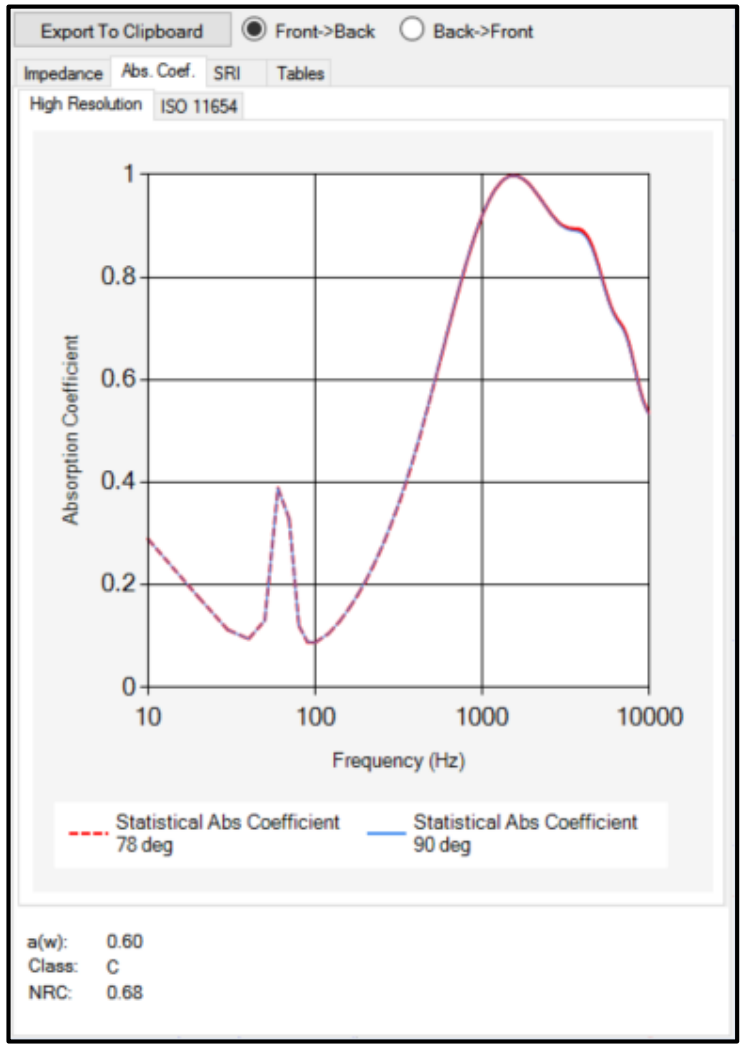
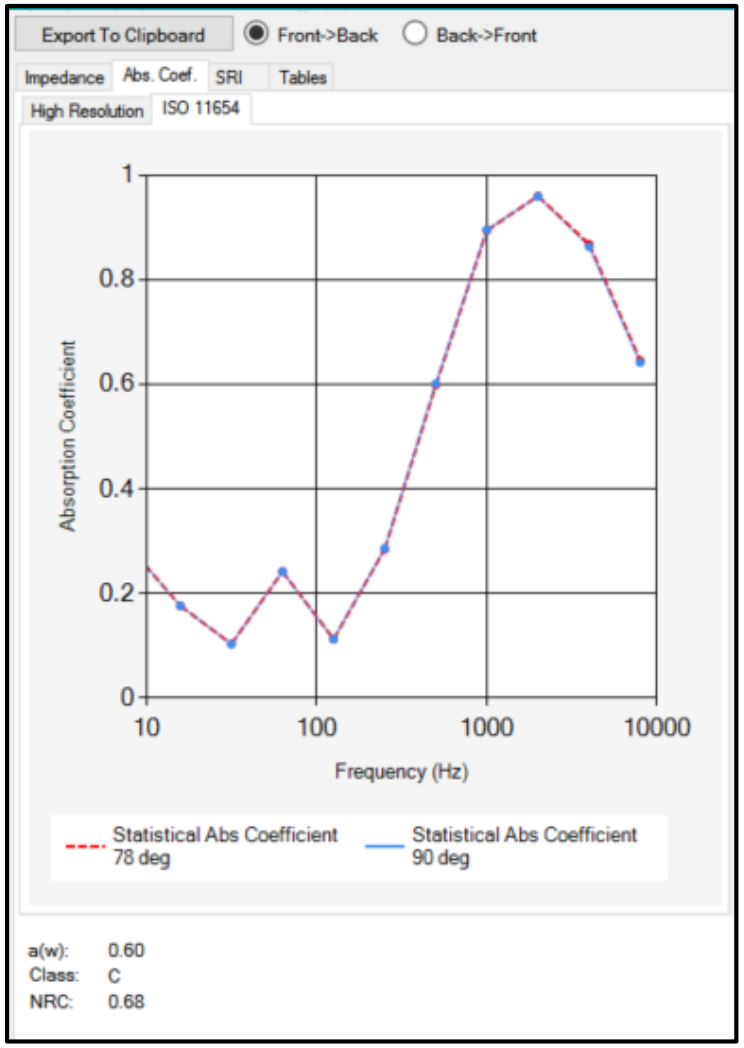
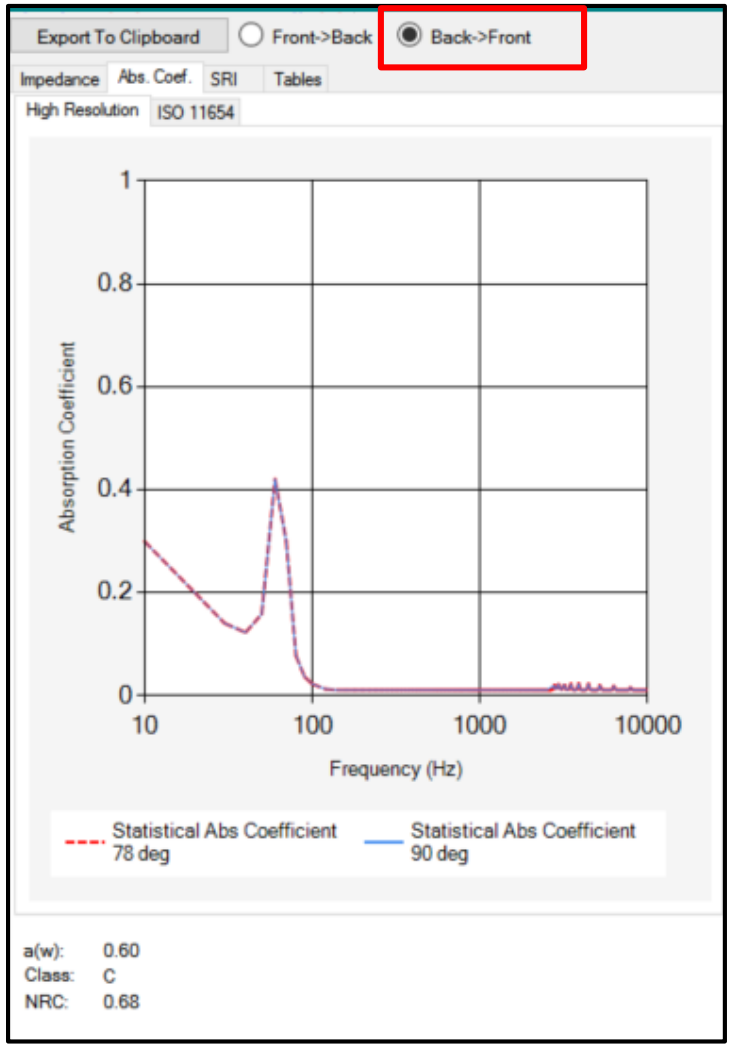
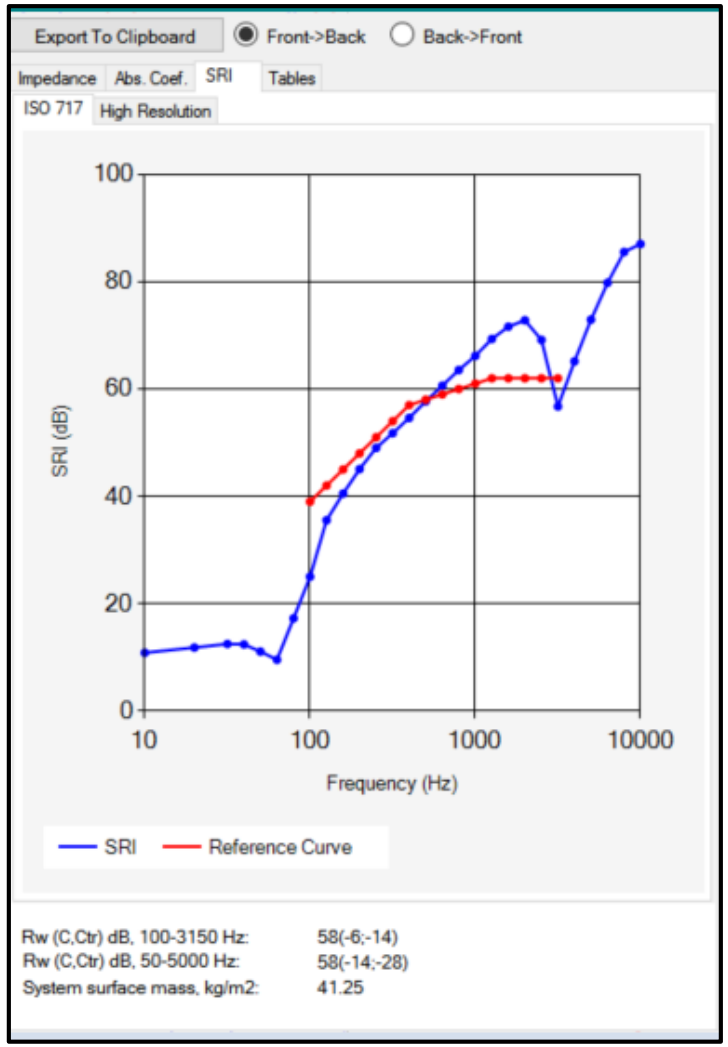
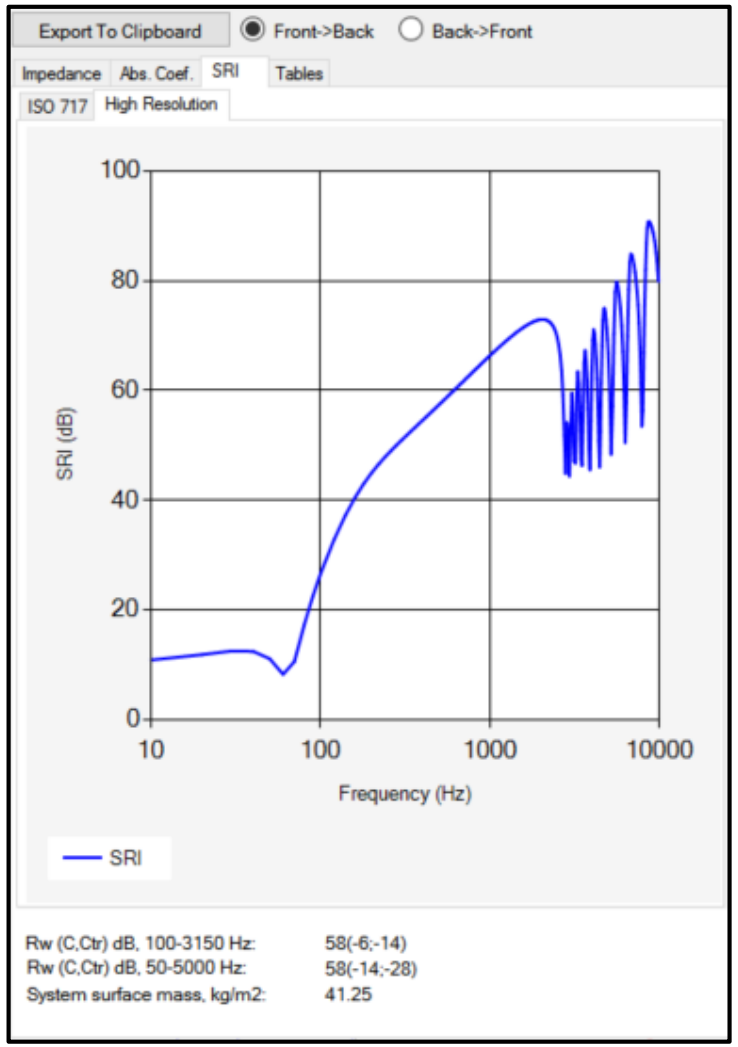






PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

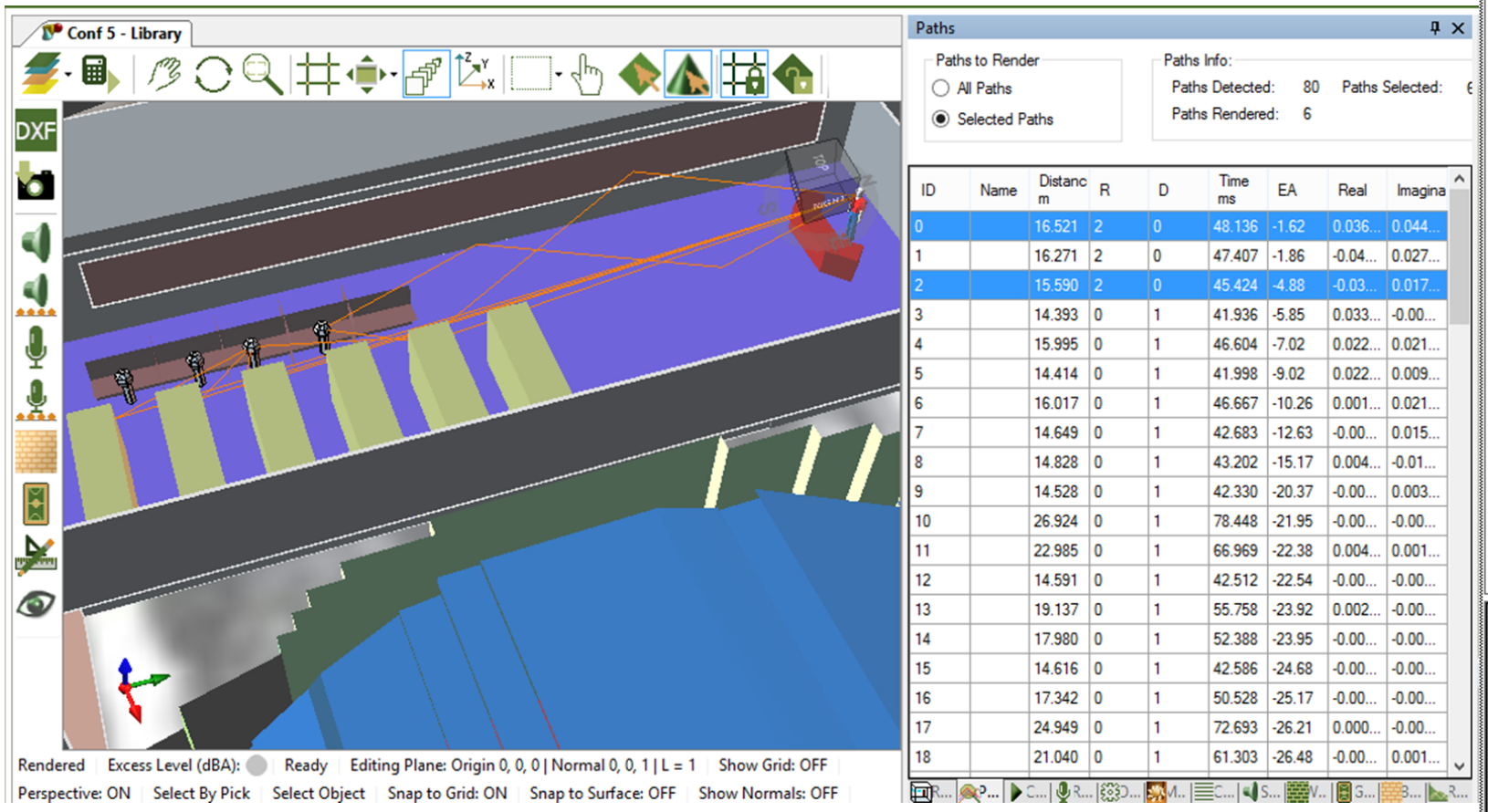




PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

INVESTIGATING STI USING ISO 3382-3:2012

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

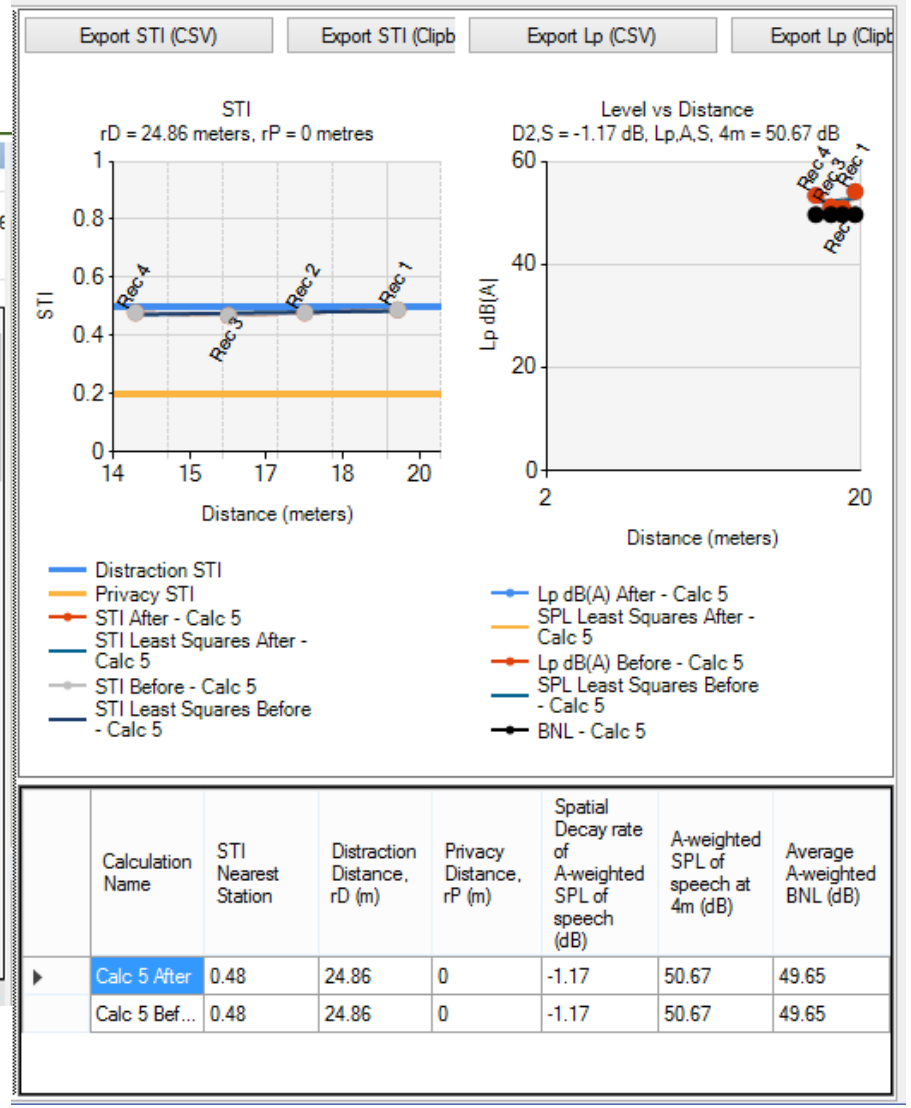


Paths

Paths to Render
- All Paths
- Selected Paths

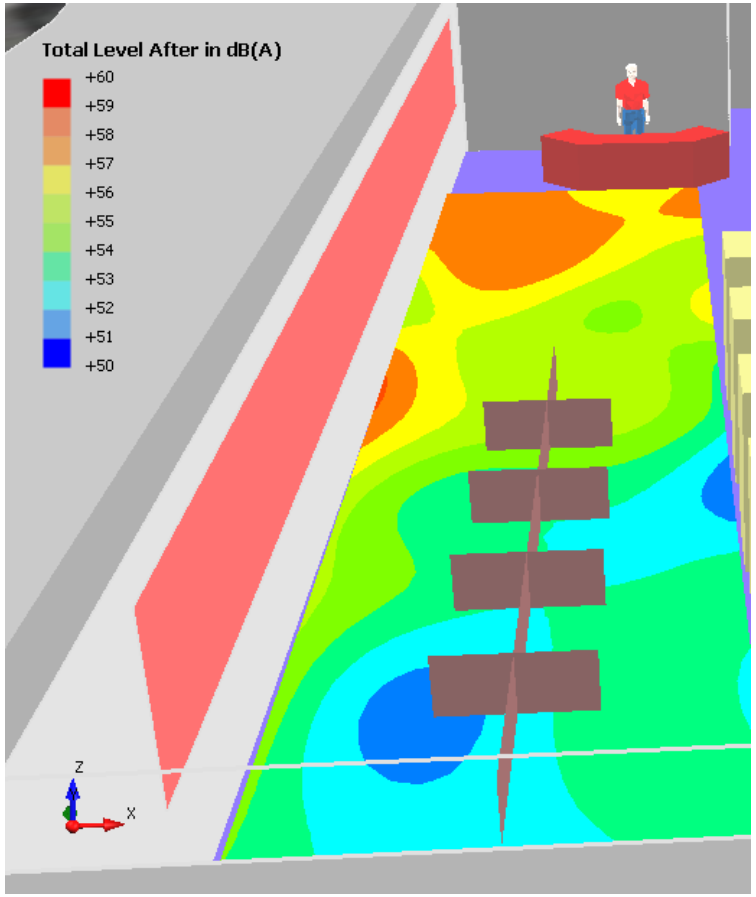
Paths Info:
Paths Detected: 80 Paths Selected: 6
Paths Rendered: 6

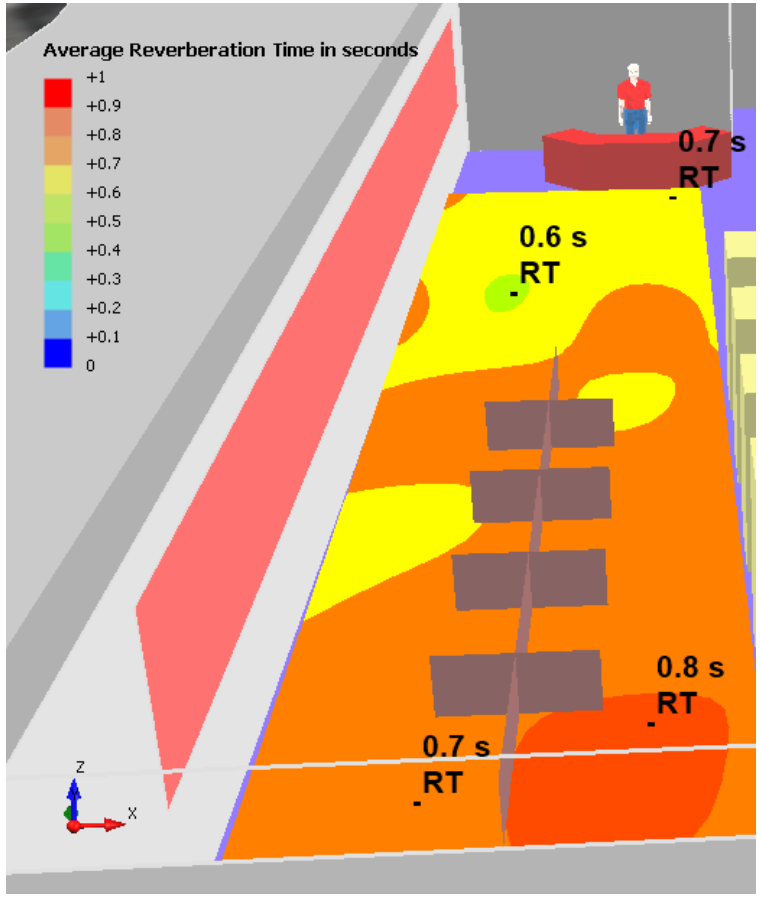
ID	Name	Distanc m	R	D	Time ms	EA	Real	Imagina
0		16.521	2	0	48.136	-1.62	0.036...	0.044...
1		16.271	2	0	47.407	-1.86	-0.04...	0.027...
2		15.590	2	0	45.424	-4.88	-0.03...	0.017...
3		14.393	0	1	41.936	-5.85	0.033...	-0.00...
4		15.995	0	1	46.604	-7.02	0.022...	0.021...
5		14.414	0	1	41.998	-9.02	0.022...	0.009...
6		16.017	0	1	46.667	-10.26	0.001...	0.021...
7		14.649	0	1	42.683	-12.63	-0.00...	0.015...
8		14.828	0	1	43.202	-15.17	0.004...	-0.01...
9		14.528	0	1	42.330	-20.37	-0.00...	0.003...
10		26.924	0	1	78.448	-21.95	-0.00...	-0.00...
11		22.985	0	1	66.969	-22.38	0.004...	0.001...
12		14.591	0	1	42.512	-22.54	-0.00...	-0.00...
13		19.137	0	1	55.758	-23.92	0.002...	-0.00...
14		17.980	0	1	52.388	-23.95	-0.00...	-0.00...
15		14.616	0	1	42.586	-24.68	-0.00...	-0.00...
16		17.342	0	1	50.528	-25.17	-0.00...	-0.00...
17		24.949	0	1	72.693	-26.21	0.000...	-0.00...
18		21.040	0	1	61.303	-26.48	-0.00...	0.001...

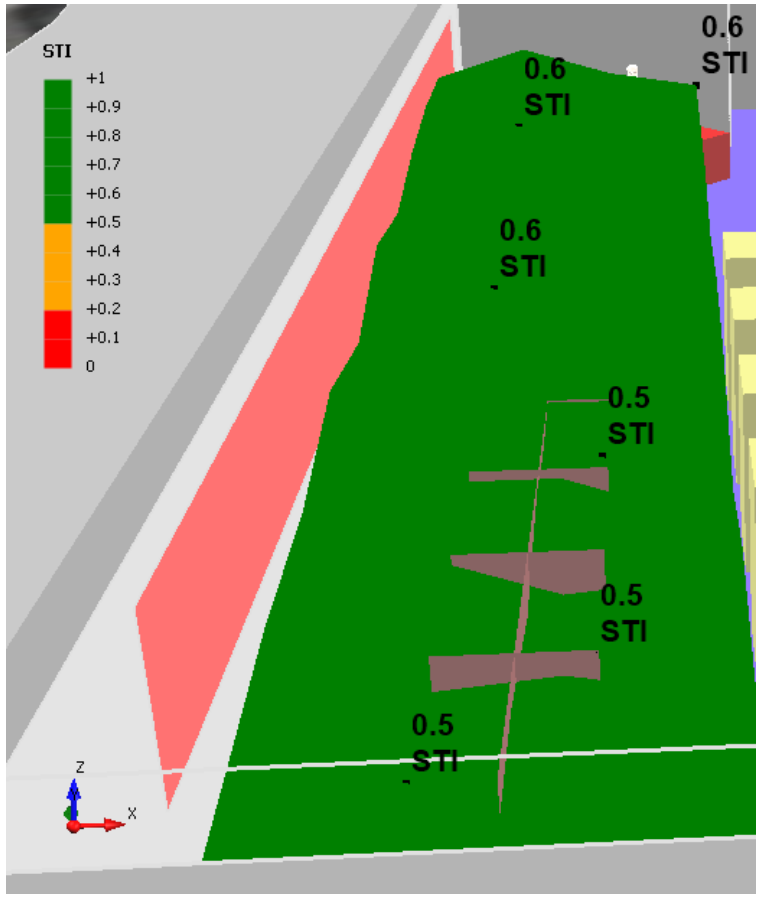


Calculation Name	STI Nearest Station	Distraction Distance, rD (m)	Privacy Distance, rP (m)	Spatial Decay rate of A-weighted SPL of speech (dB)	A-weighted SPL of speech at 4m (dB)	Average A-weighted BNL (dB)
Calc 5 After	0.48	24.86	0	-1.17	50.67	49.65
Calc 5 Bef...	0.48	24.86	0	-1.17	50.67	49.65

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

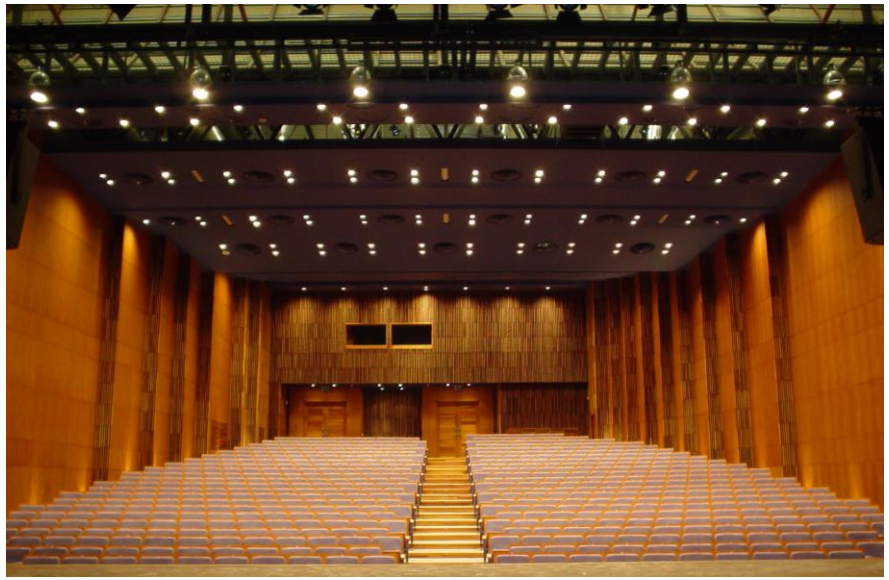




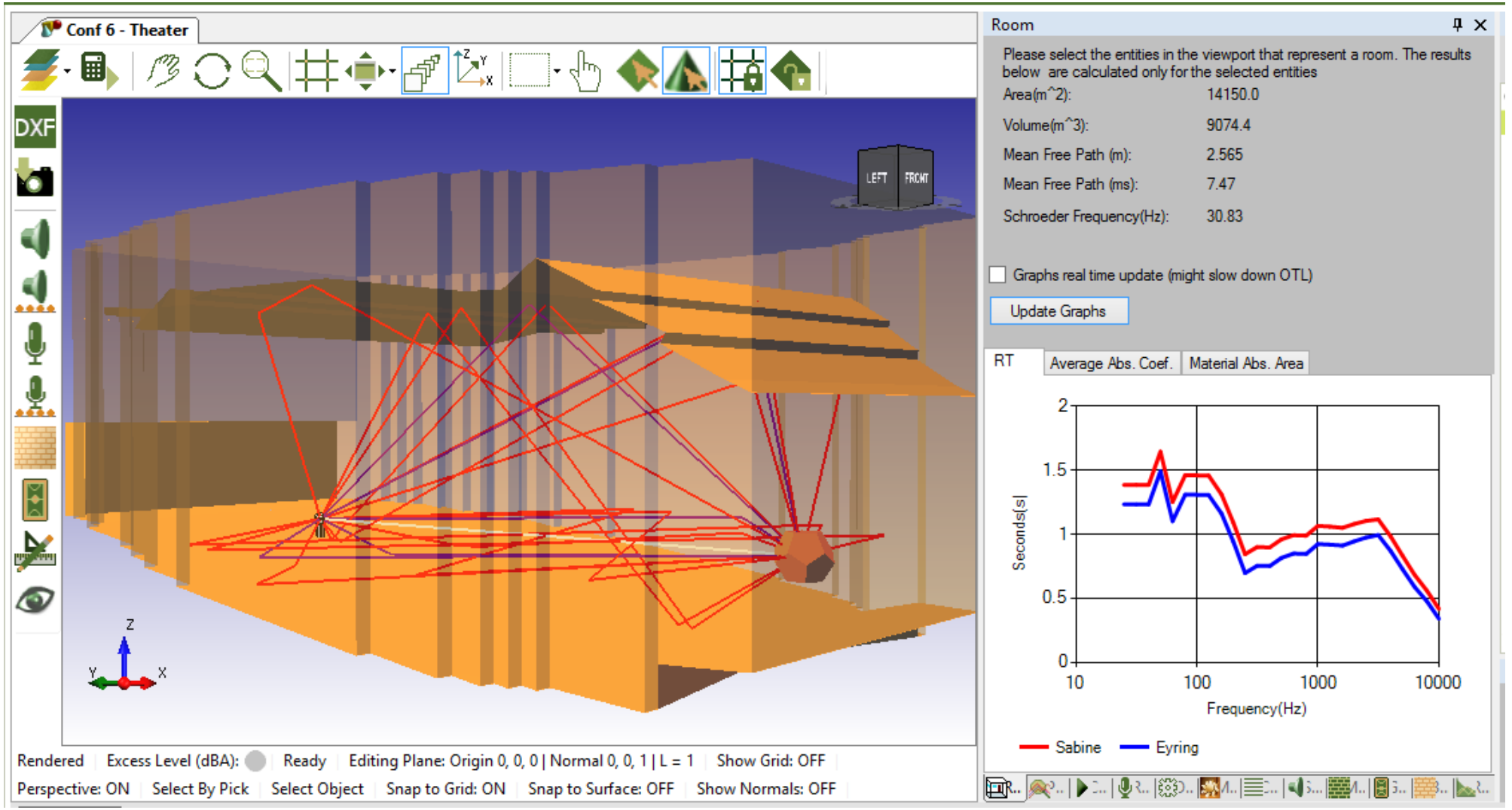


PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

INVESTIGATING THE THEATRE USING ISO 3382-1:2009



PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS



PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS

Impulse Response | Room Acoustics | Auralisation

Decay | Clarity and Strength | Definition | STI | Room Param

Parameters: EDT, Sabine, T20, Eyring, T30, Centre Time, T60

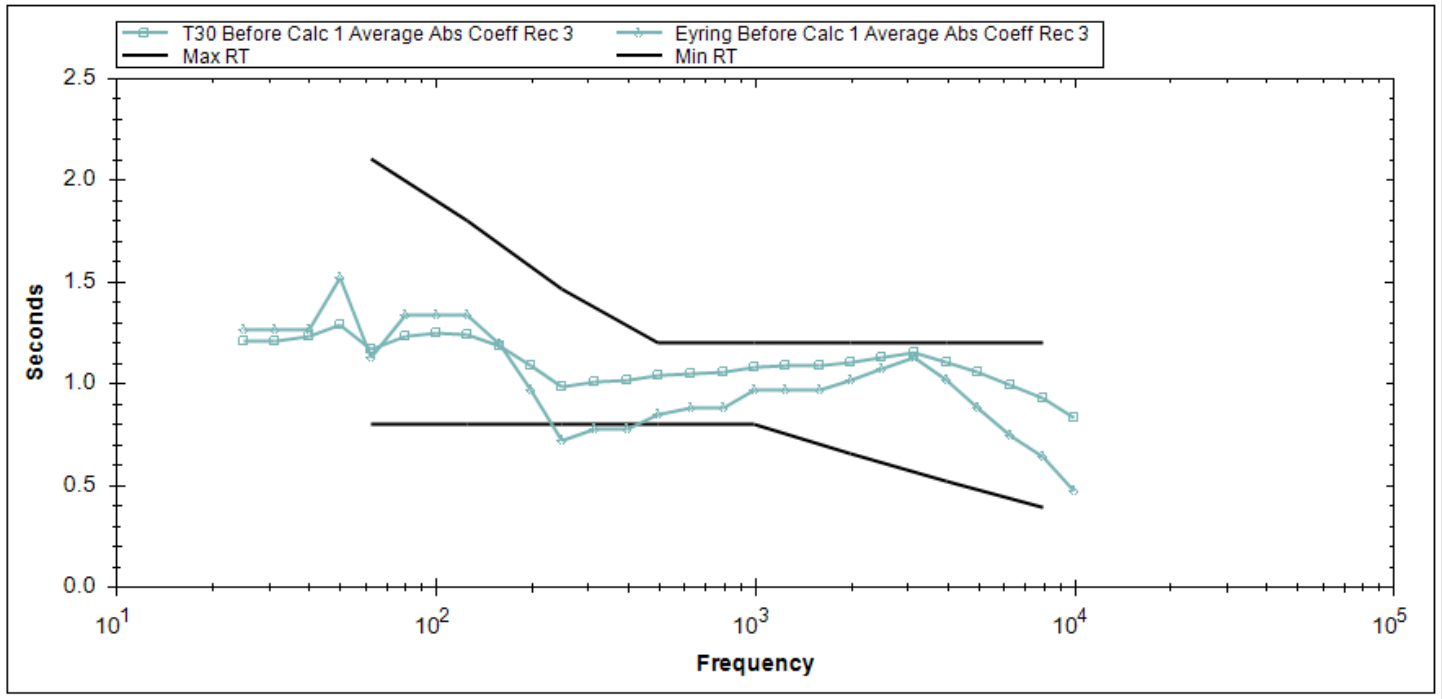
RT Criteria — RT at 500 Hz: 1.00 — Margin (%): 20

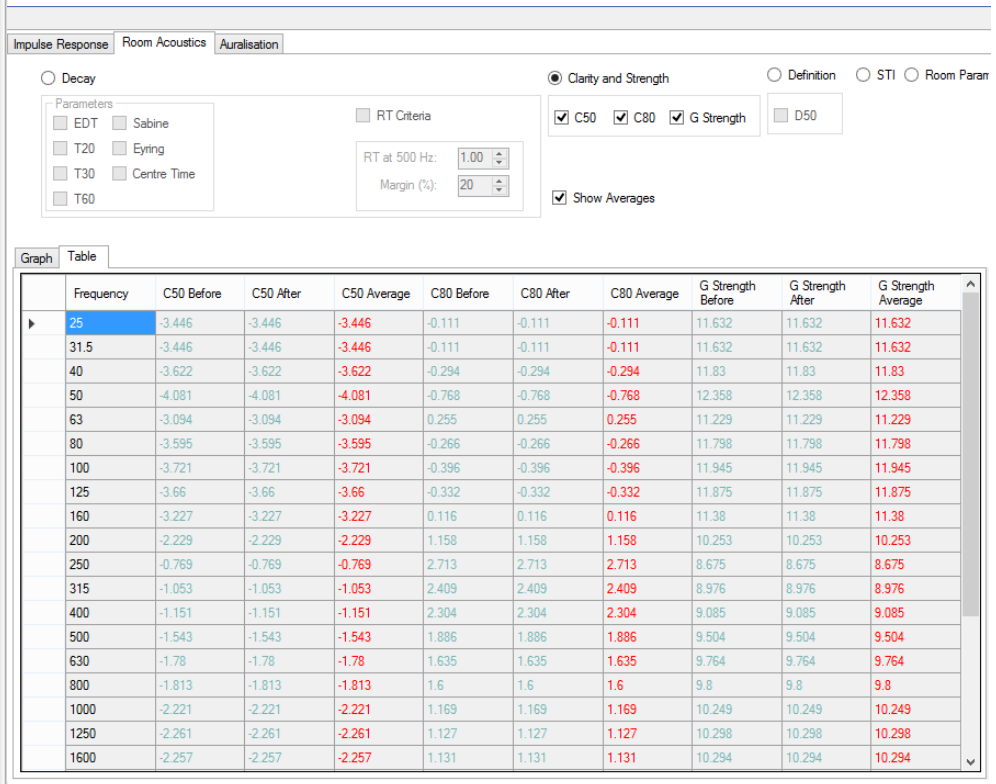
C50, C80, G Strength, D50

Show Averages

Graph | Table

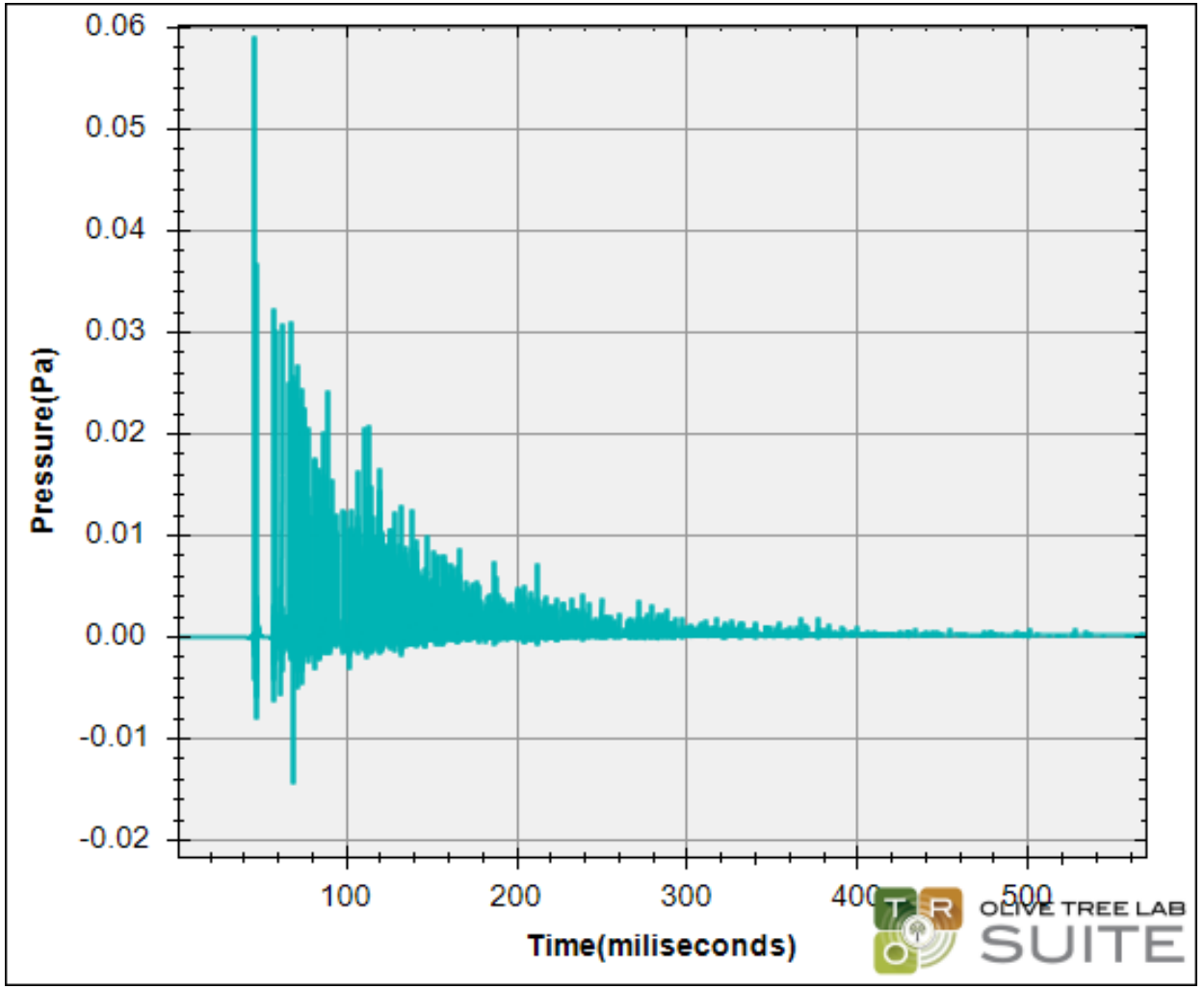
Autoscale | Log X Axis





Frequency	C50 Before	C50 After	C50 Average	C80 Before	C80 After	C80 Average	G Strength Before	G Strength After	G Strength Average
25	-3.446	-3.446	-3.446	-0.111	-0.111	-0.111	11.632	11.632	11.632
31.5	-3.446	-3.446	-3.446	-0.111	-0.111	-0.111	11.632	11.632	11.632
40	-3.622	-3.622	-3.622	-0.294	-0.294	-0.294	11.83	11.83	11.83
50	-4.081	-4.081	-4.081	-0.768	-0.768	-0.768	12.358	12.358	12.358
63	-3.094	-3.094	-3.094	0.255	0.255	0.255	11.229	11.229	11.229
80	-3.595	-3.595	-3.595	-0.266	-0.266	-0.266	11.798	11.798	11.798
100	-3.721	-3.721	-3.721	-0.396	-0.396	-0.396	11.945	11.945	11.945
125	-3.66	-3.66	-3.66	-0.332	-0.332	-0.332	11.875	11.875	11.875
160	-3.227	-3.227	-3.227	0.116	0.116	0.116	11.38	11.38	11.38
200	-2.229	-2.229	-2.229	1.158	1.158	1.158	10.253	10.253	10.253
250	-0.769	-0.769	-0.769	2.713	2.713	2.713	8.675	8.675	8.675
315	-1.053	-1.053	-1.053	2.409	2.409	2.409	8.976	8.976	8.976
400	-1.151	-1.151	-1.151	2.304	2.304	2.304	9.085	9.085	9.085
500	-1.543	-1.543	-1.543	1.886	1.886	1.886	9.504	9.504	9.504
630	-1.78	-1.78	-1.78	1.635	1.635	1.635	9.764	9.764	9.764
800	-1.813	-1.813	-1.813	1.6	1.6	1.6	9.8	9.8	9.8
1000	-2.221	-2.221	-2.221	1.169	1.169	1.169	10.249	10.249	10.249
1250	-2.261	-2.261	-2.261	1.127	1.127	1.127	10.298	10.298	10.298
1600	-2.257	-2.257	-2.257	1.131	1.131	1.131	10.294	10.294	10.294

PART 3: AN EXAMPLE OF INTEGRATED ACOUSTICS



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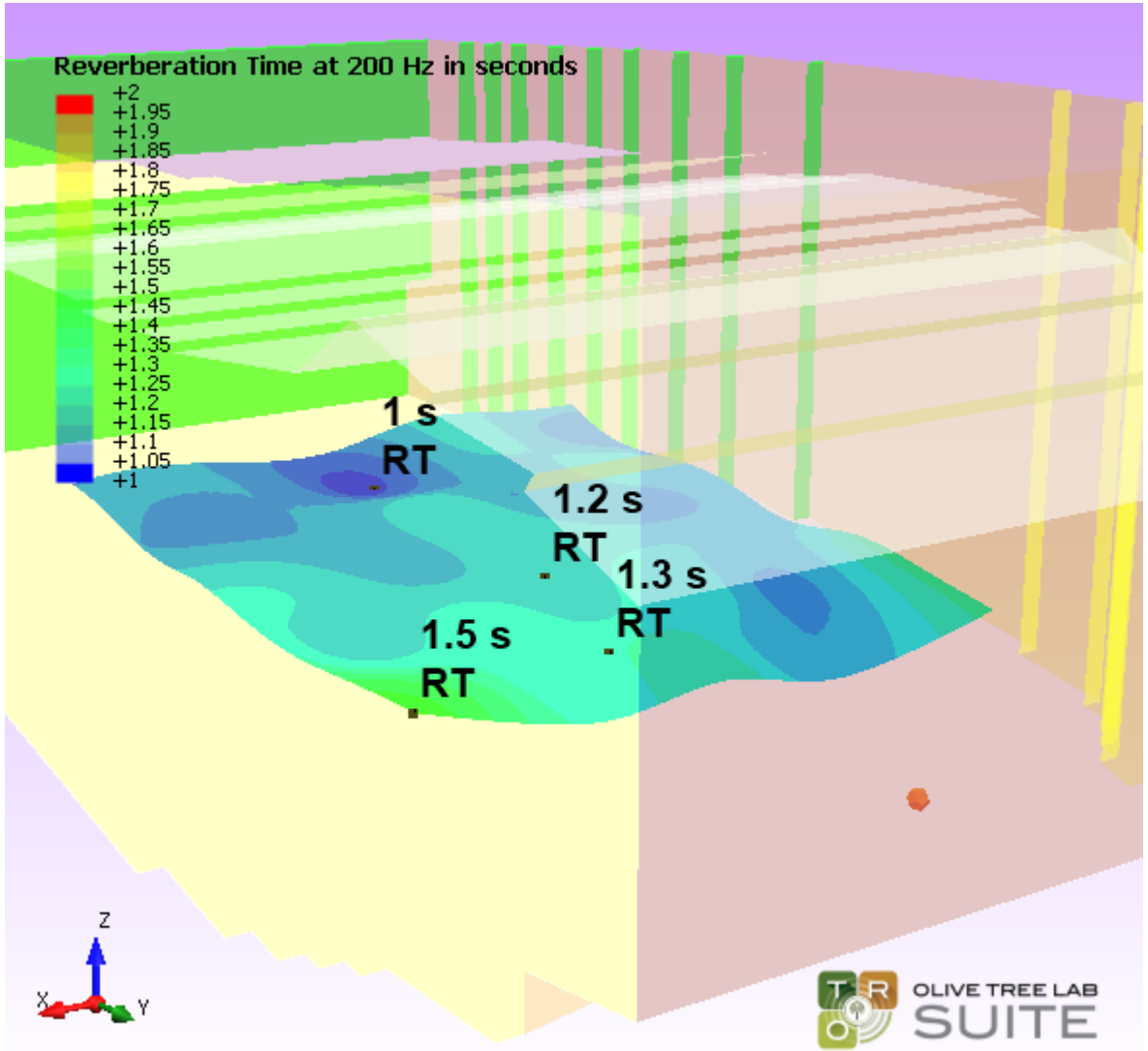

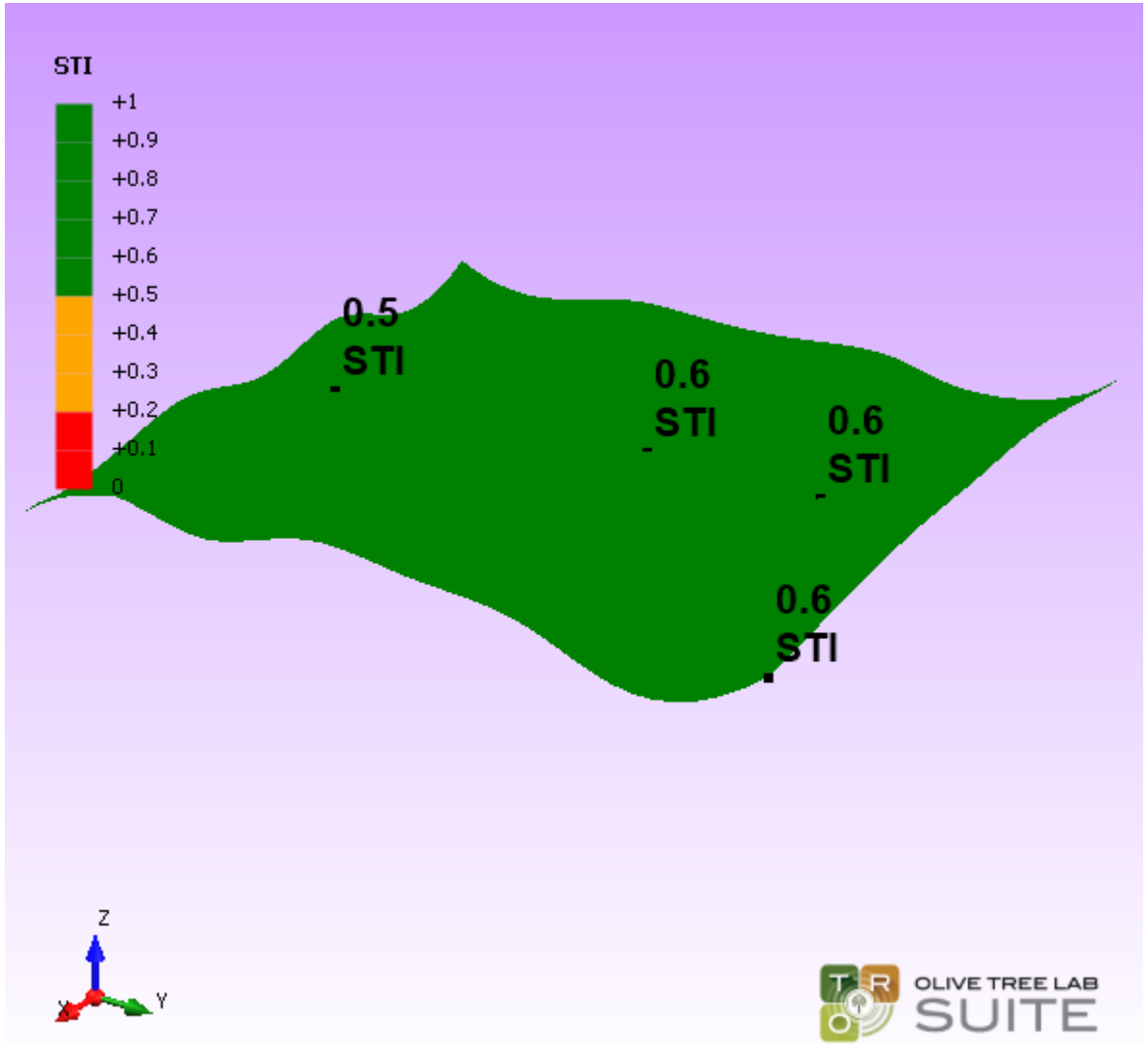

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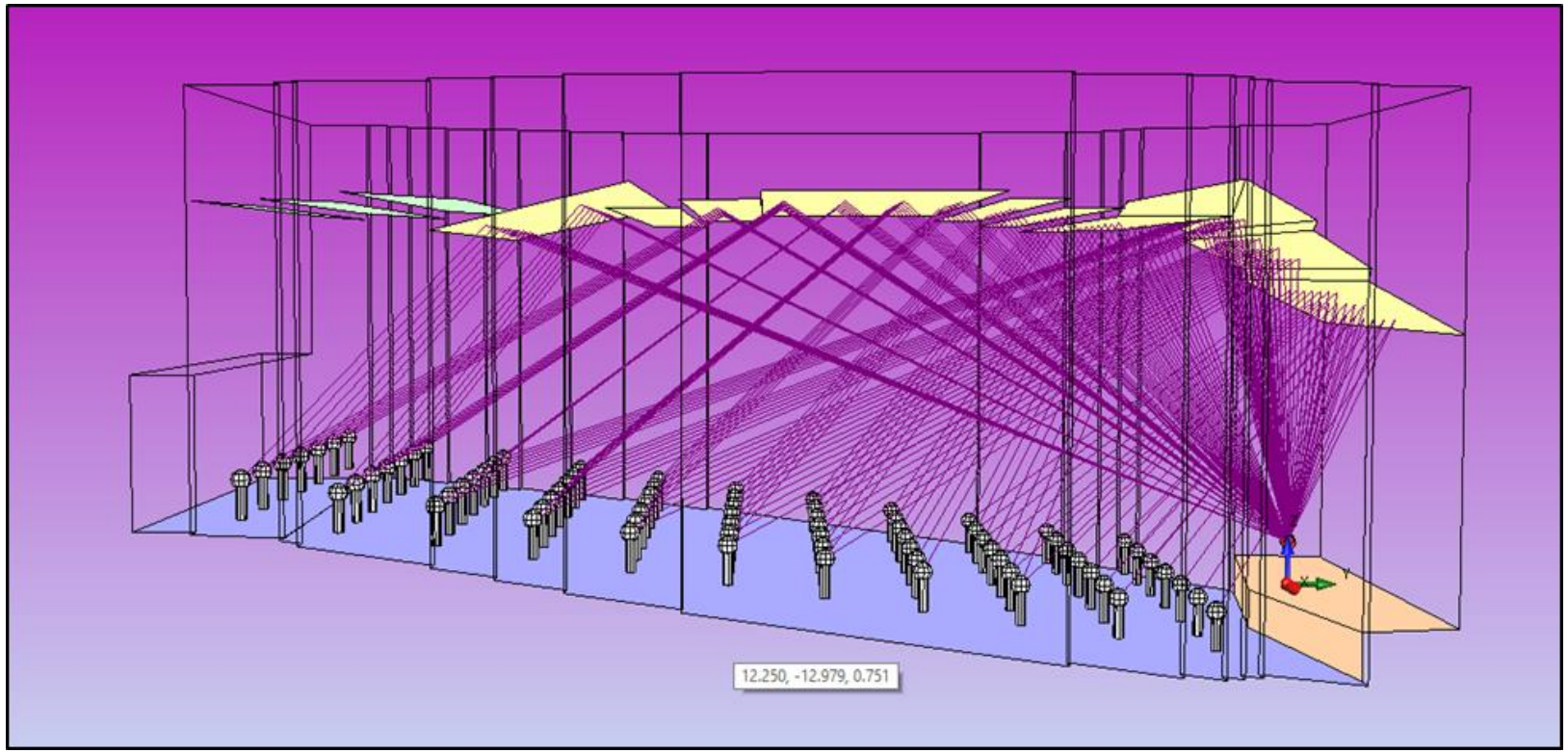

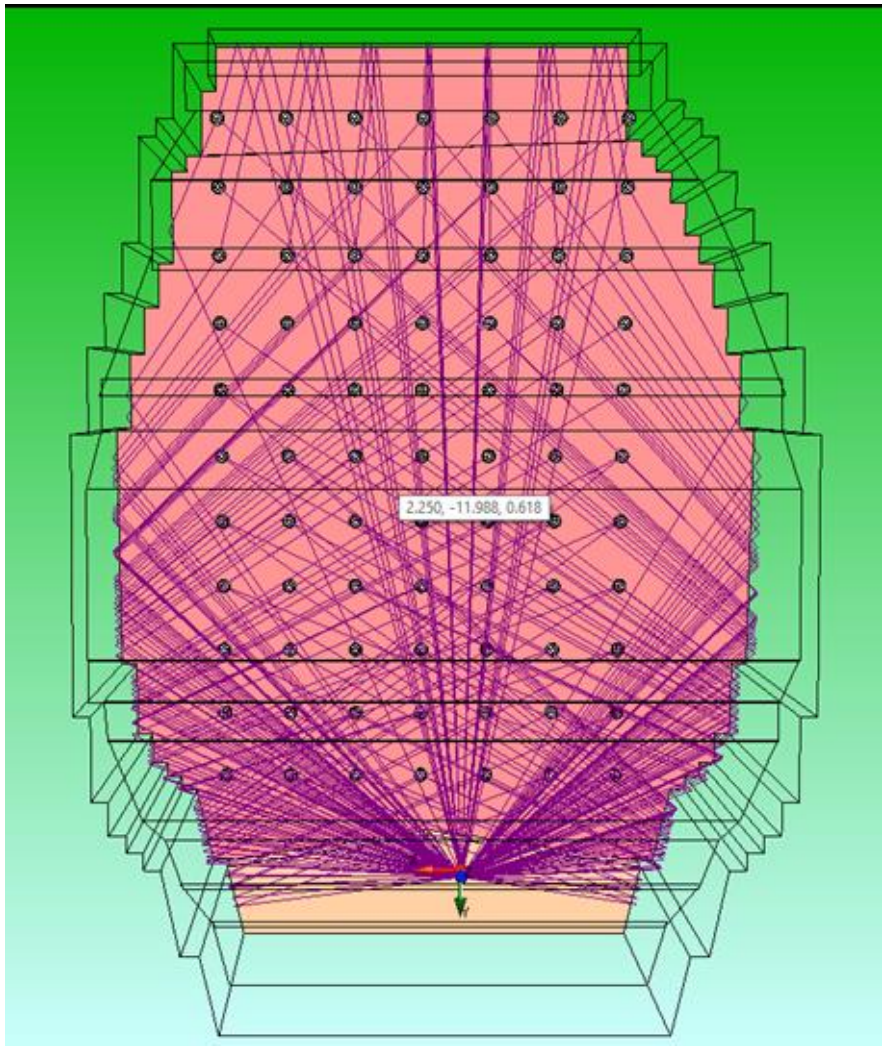

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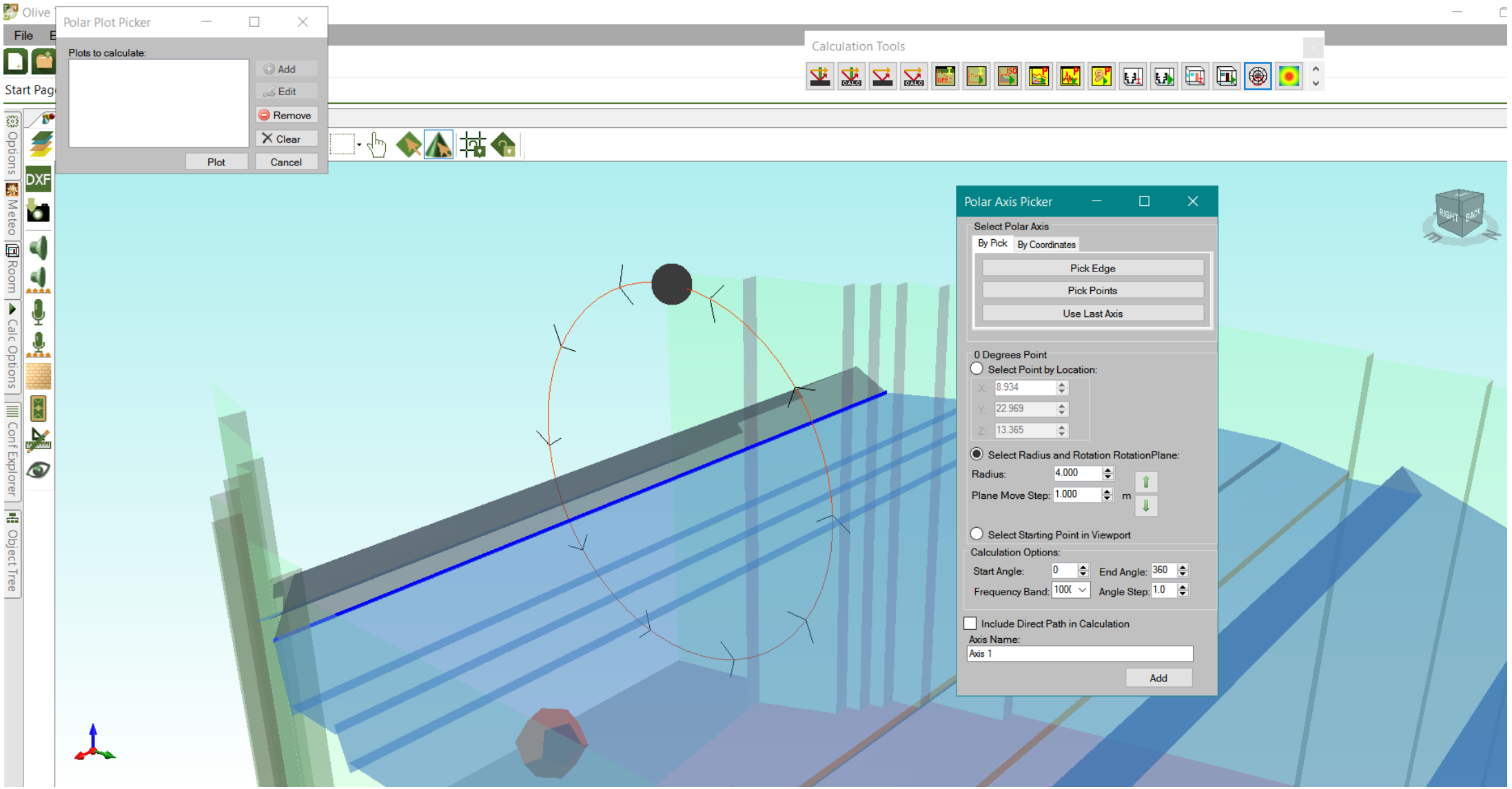

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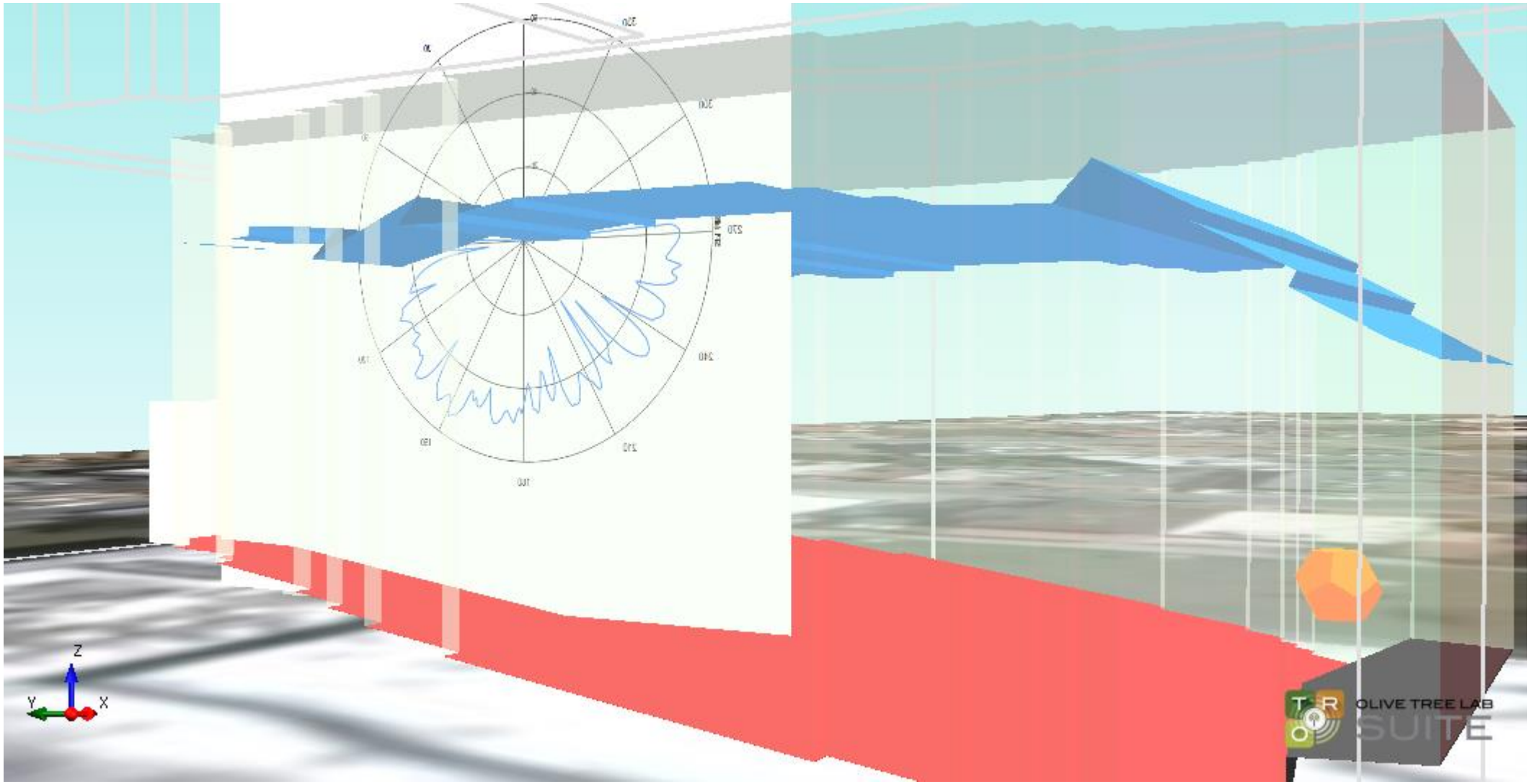

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THANK YOU

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