THE SIGNIFICANCE OF SOUND DIFFRACTION EFFECTS IN PREDICTING ACOUSTICS IN ANCIENT THEATRES

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- Are Sound Diffraction effects significant in predicting acoustics in ancient theatres?

- The answer is YES.

Objectives of the Project

- Measurements at the Ancient Theatre of Kourion
- Model the Theatre and simulate the acoustic behavior at the measured positions
- Compare measurement with simulation results to obtain evidence of the significance of diffraction effects

Sound measurements at Kourion Ancient Theatre

- The ancient theatre studied by us is the Ancient Theatre of Kourion, a Greek theatre of the 2nd century BC which was subsequently used by the Romans.

- Today it holds an audience of 2000 people and is used as a venue for theatre and music.

Cyprus Music Days Jazz & Classical Music Festival at Kourion

Using a laser distance meter, measurements were taken on a ray over the height of a seated audience (75cm above each step) at distances of 38.5cm on the ray.

Modelling and Simulation of Kourion Ancient Theatre

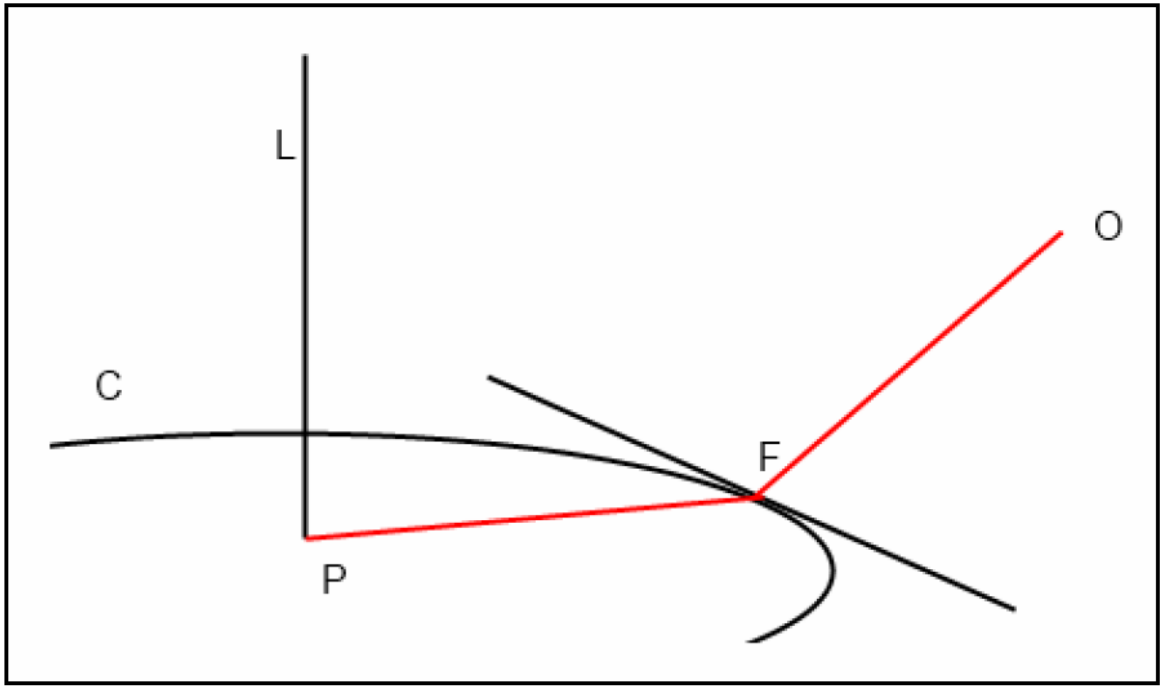
OLIVE TREE LAB

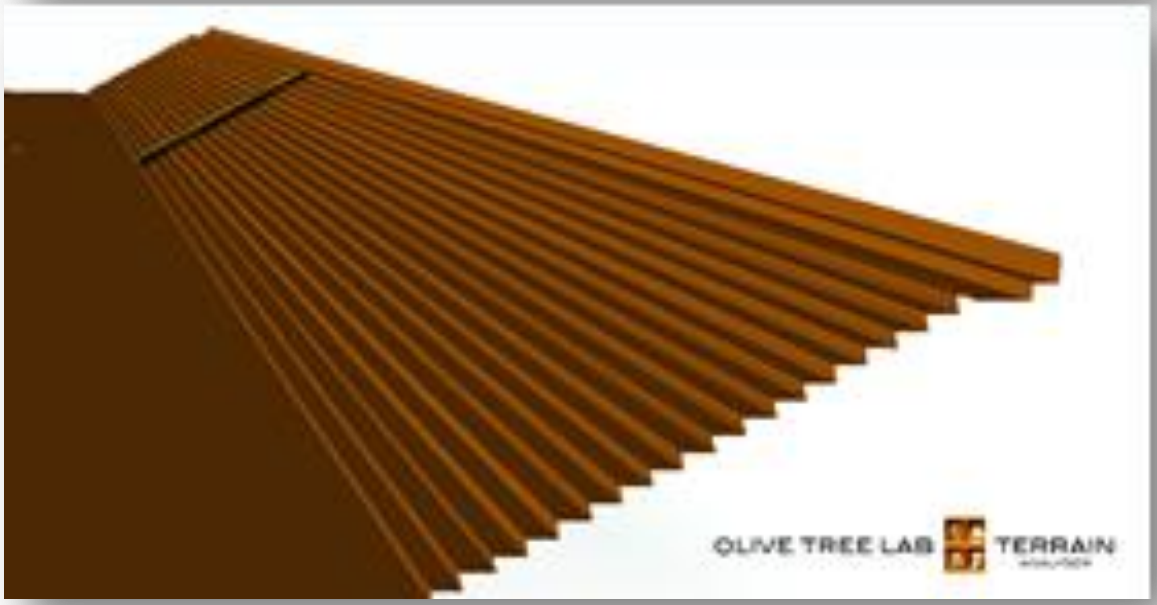
TERRAIN

- Reflection and diffraction to multiple orders
- Atmospheric absorption
- Turbulence
- Fresnel Zones
- And many more…

The Ray Equivalency Theorem

- Only one diffraction ray on the curve
- The ray on the curve is equivalent with the ray on the line




OLIVE TREE LAB
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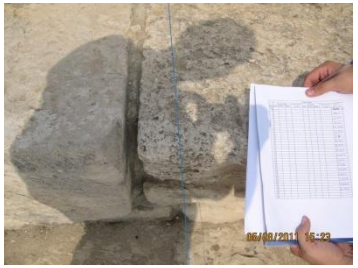
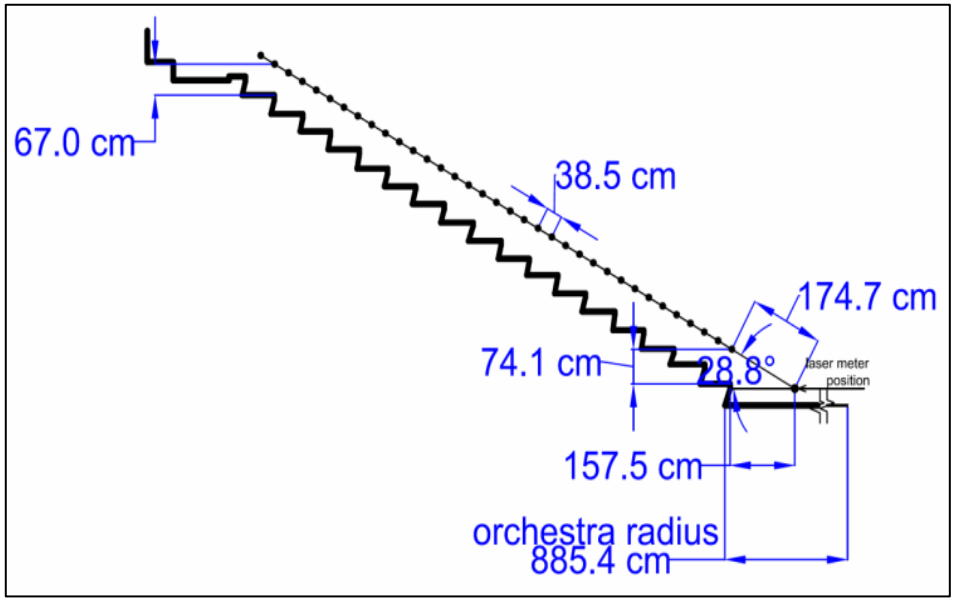
Cavea Section Imprinting

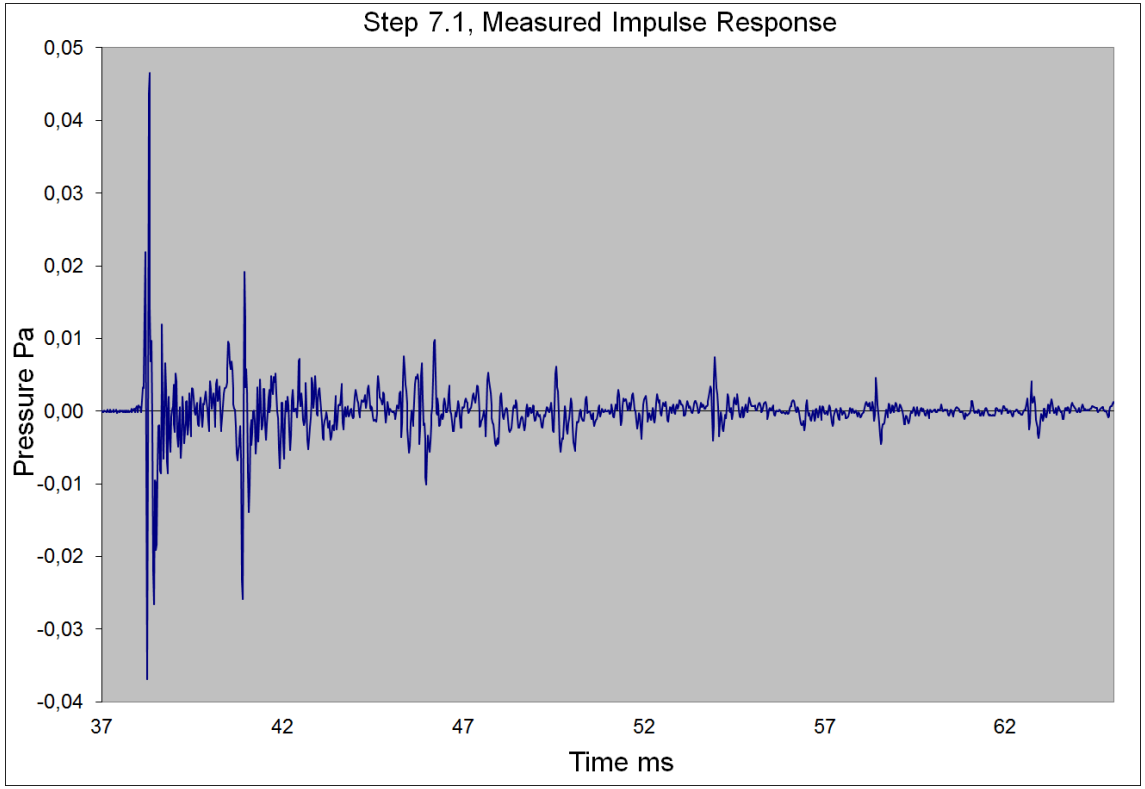




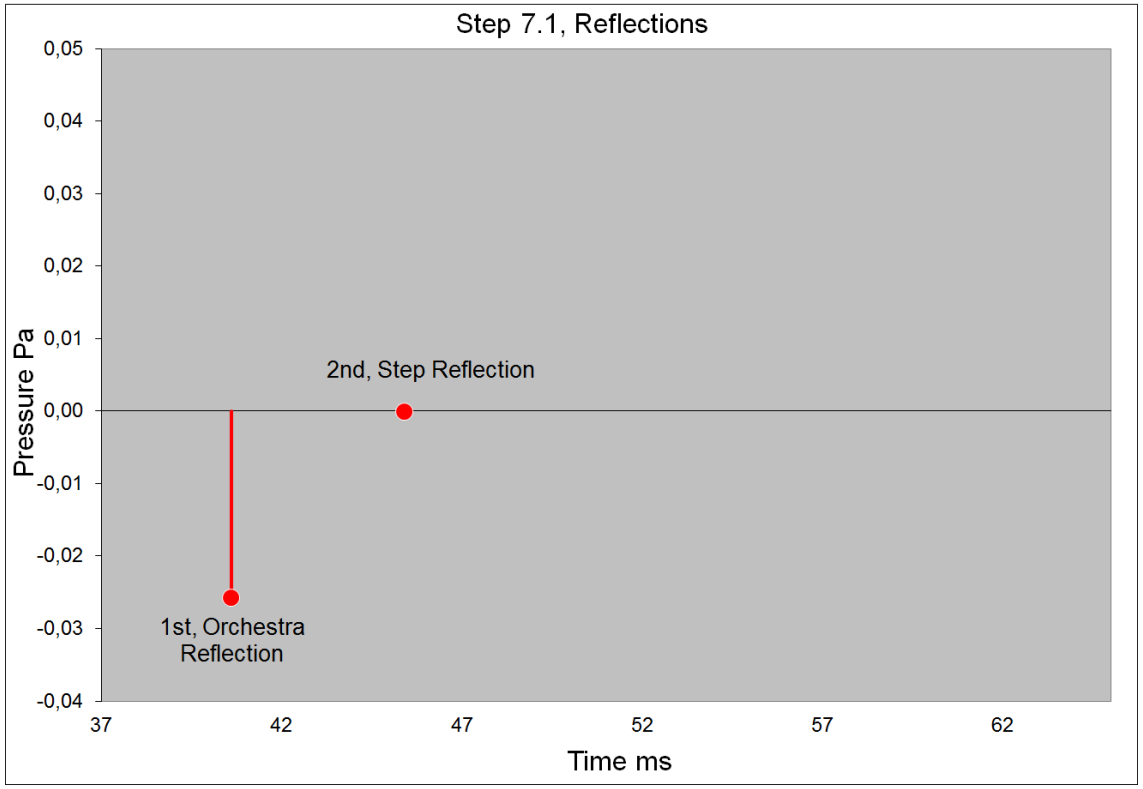
- How do we “diagnose” from measurements in ancient theatres the effects of sound diffraction?
- How do we distinguish them from sound reflections?
- What do they look like, in frequency and time response?

What follows is an effort to answer the above questions.

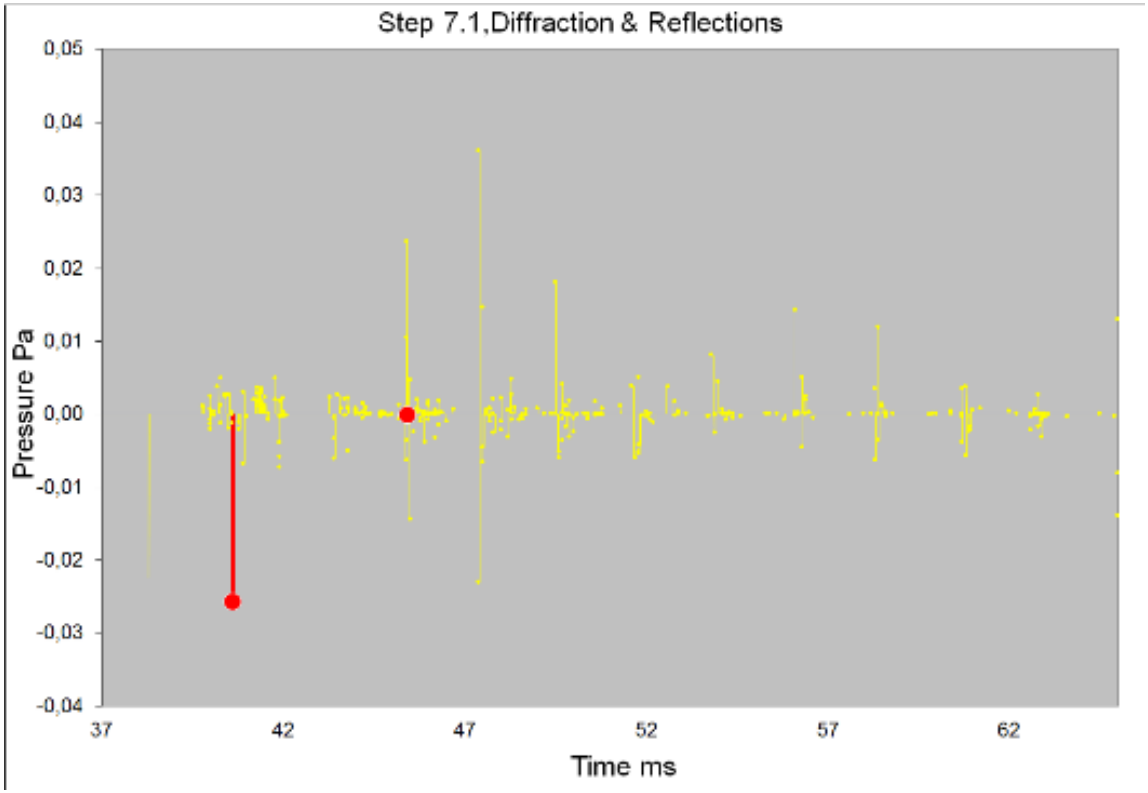
How do Diffractions look like in time domain?



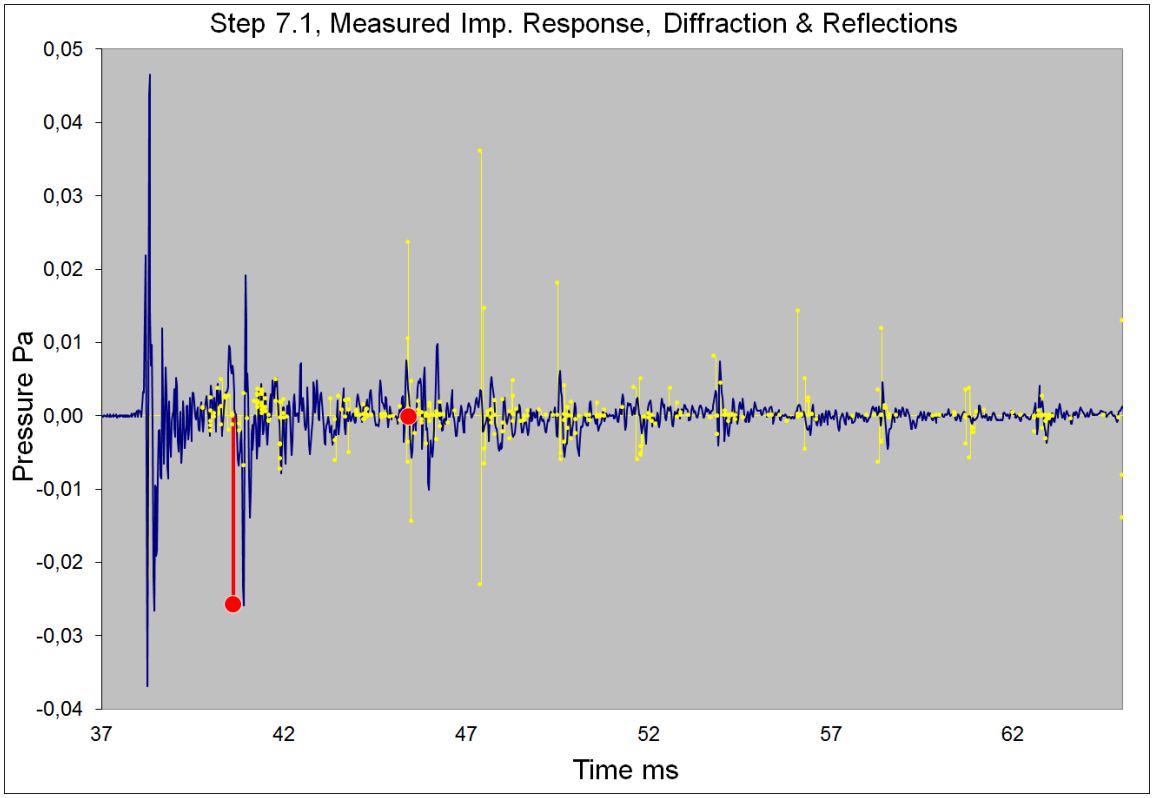
Reflections only



Reflections and diffractions



Impulse Response, Reflections and diffractions

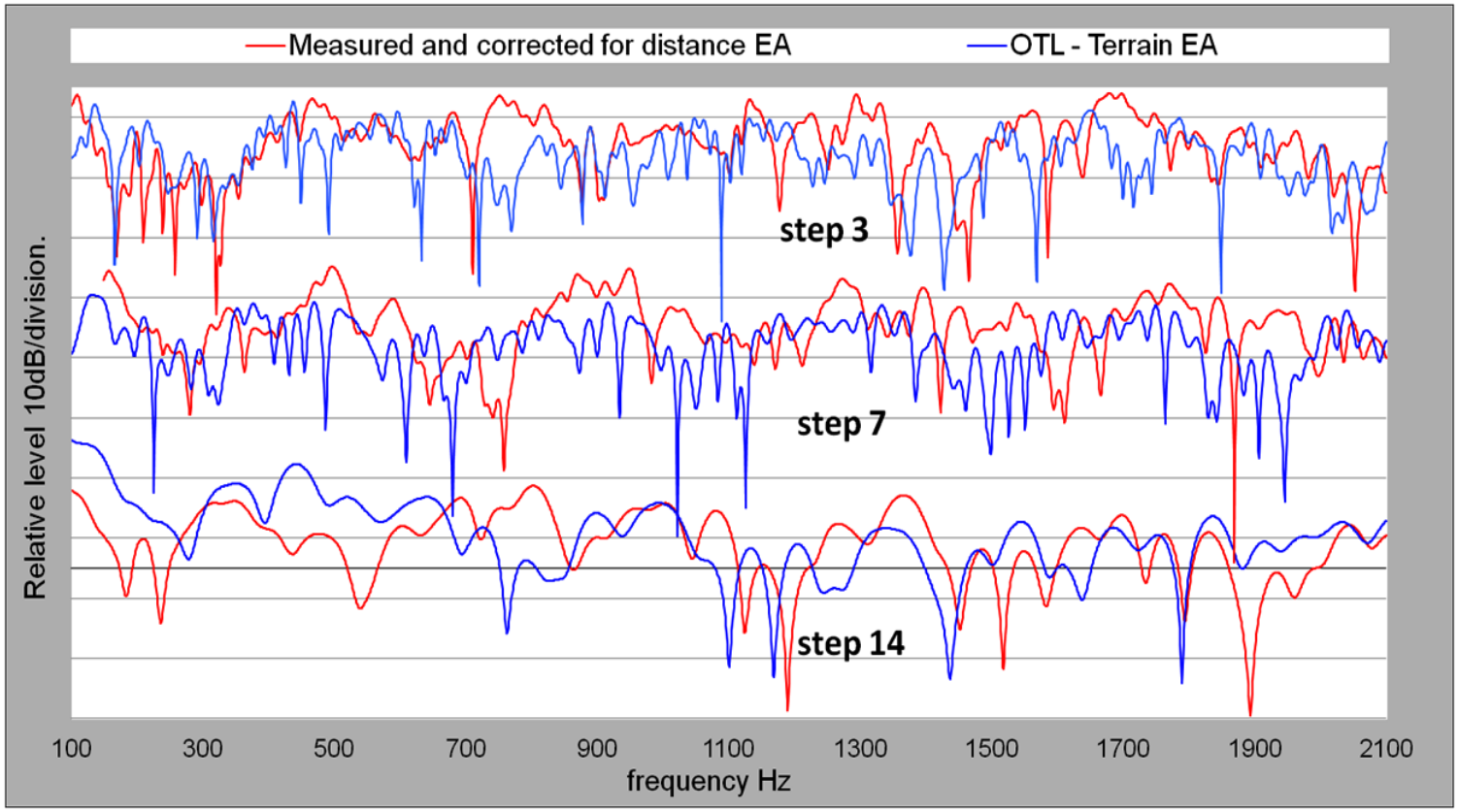


Measurement and Simulation Results

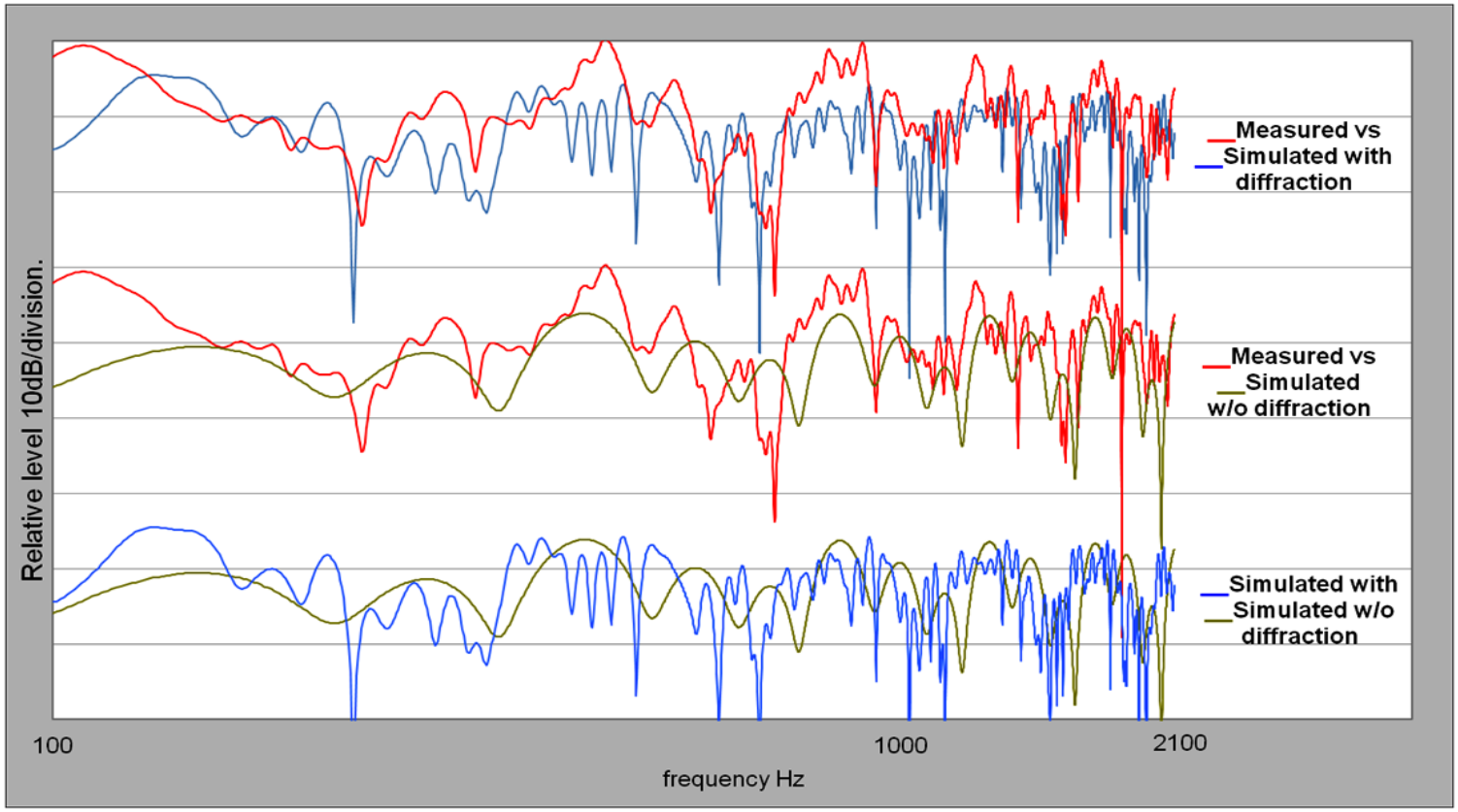
- To eliminate the effects of the loudspeaker unit we present results in ***Excess Attenuation (EA)***

- ***EA*** *is the spectrum of the ratio of the total sound pressure level at a receiver to the direct sound pressure level*.

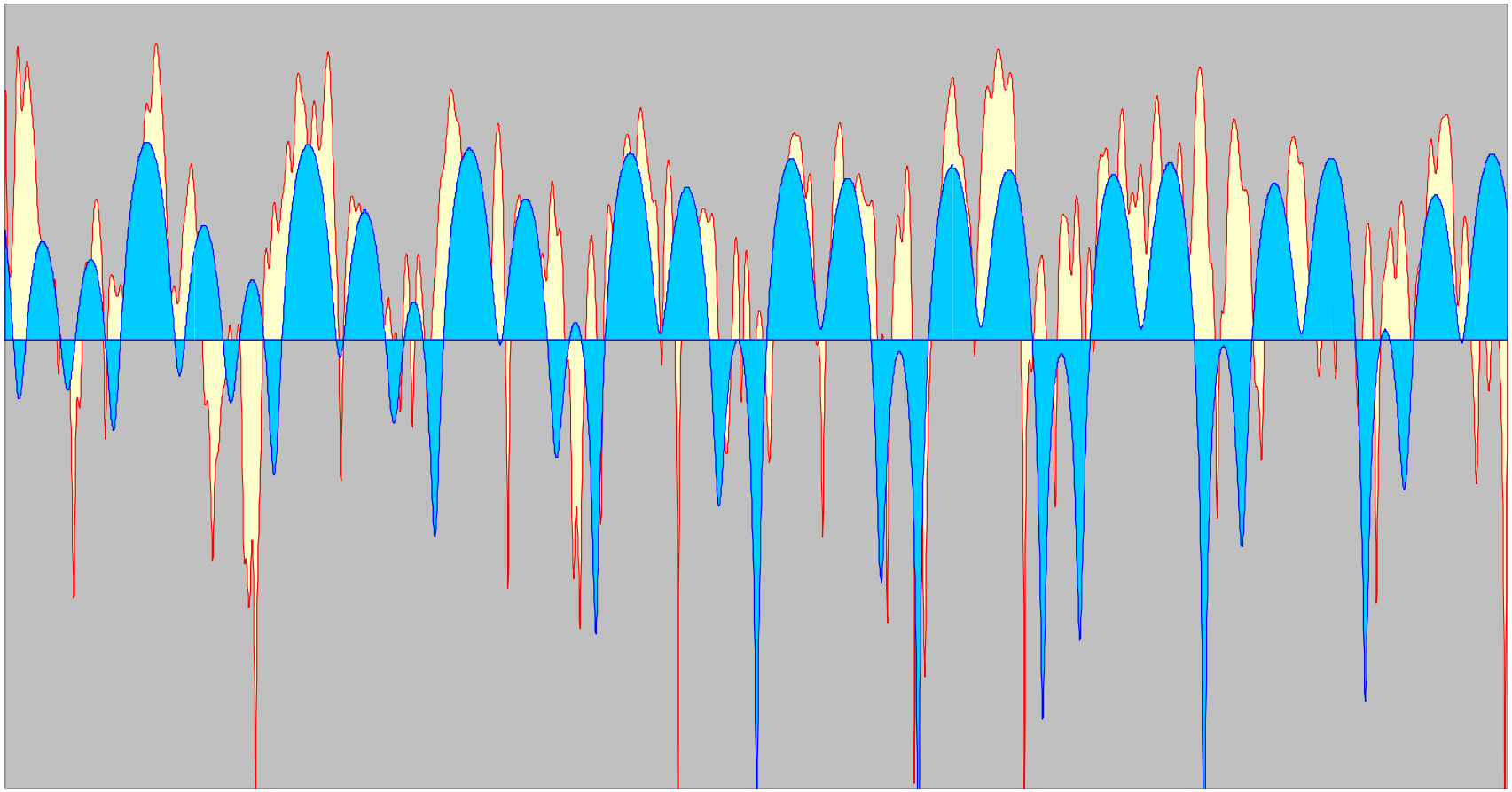
Measured vs Simulated EA at three steps



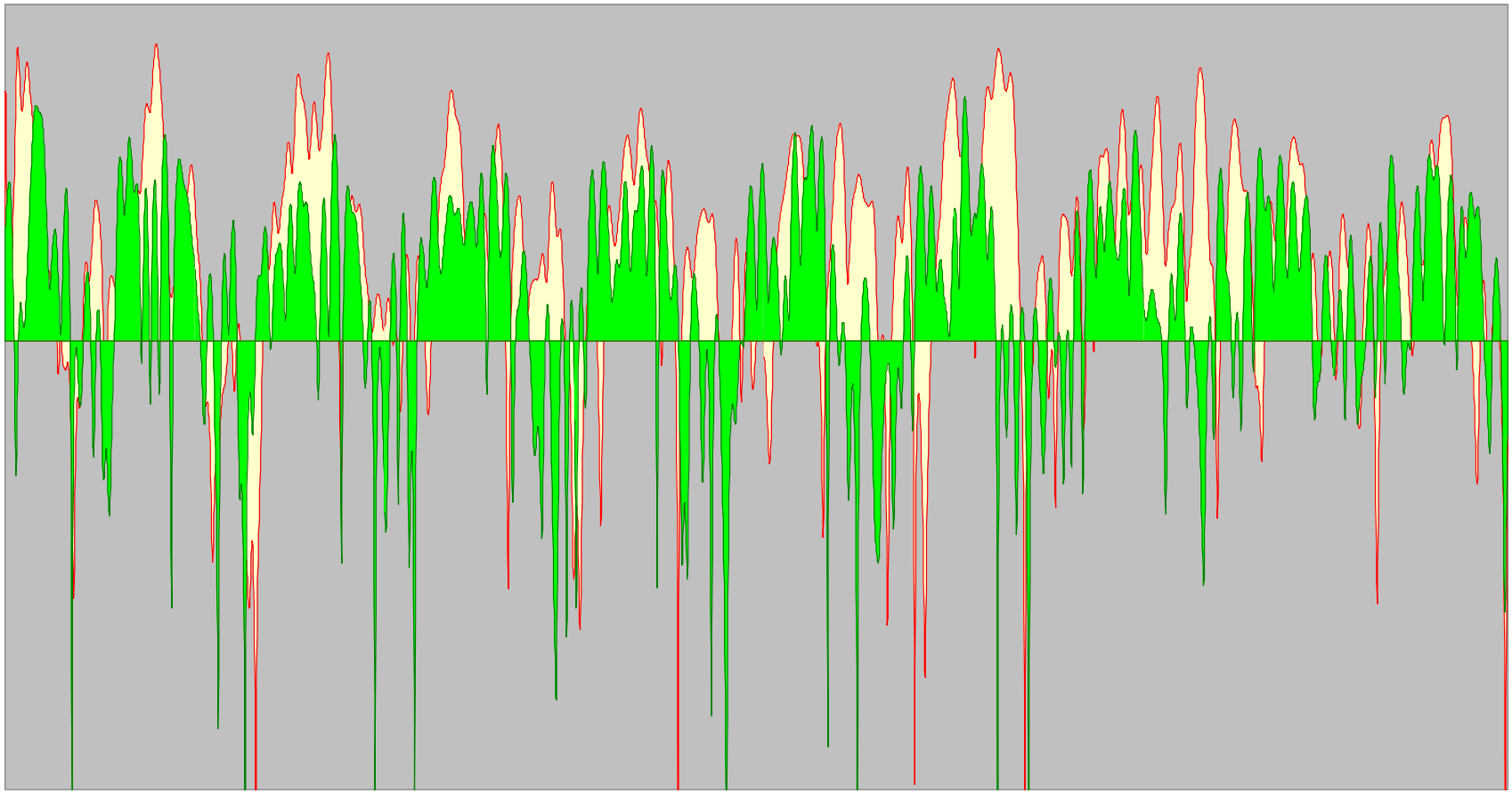
Measured vs Simulated EA
With and without diffraction



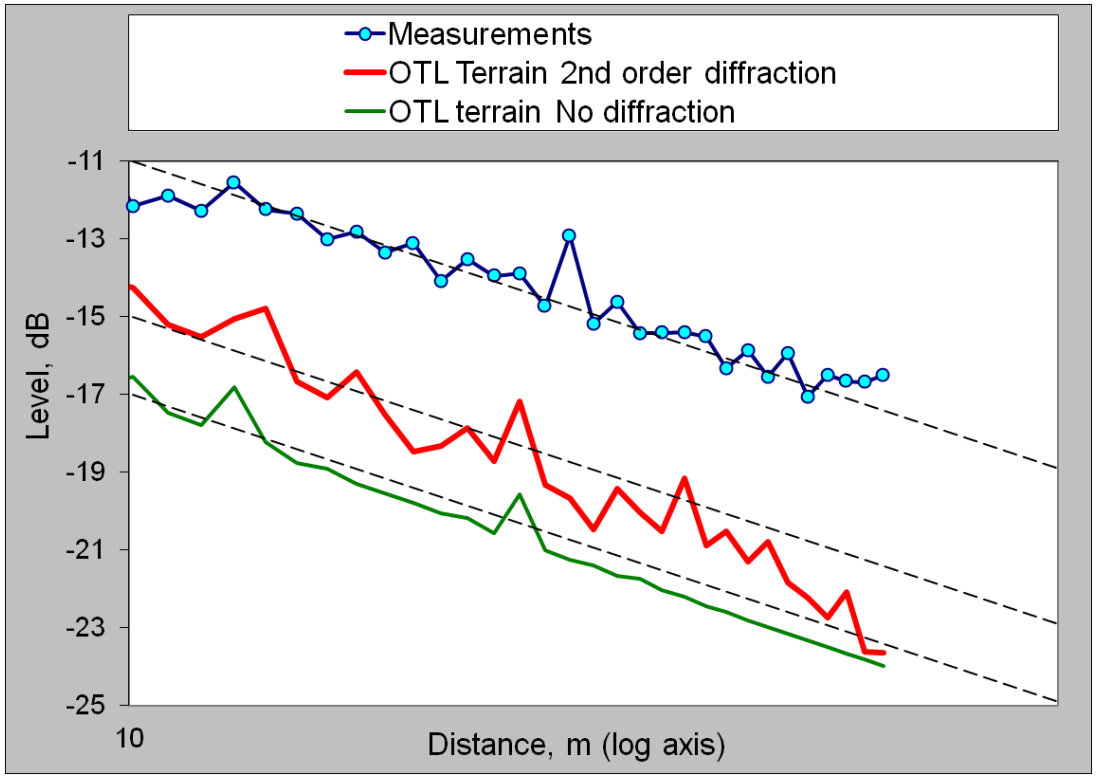
Measurements vs only reflections



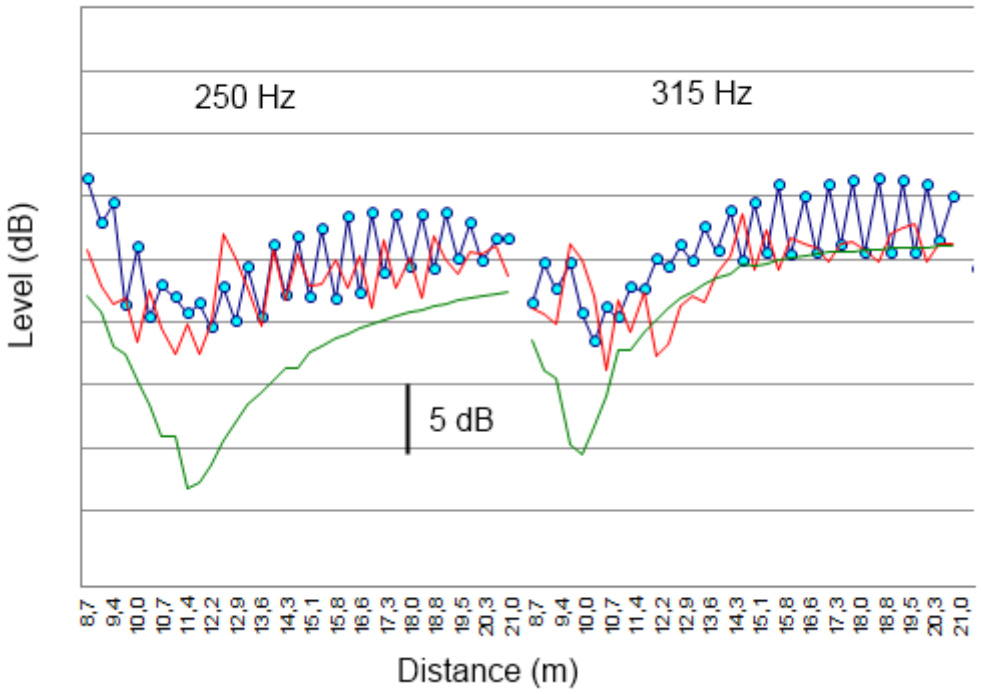
Measurements vs reflections & diffractions



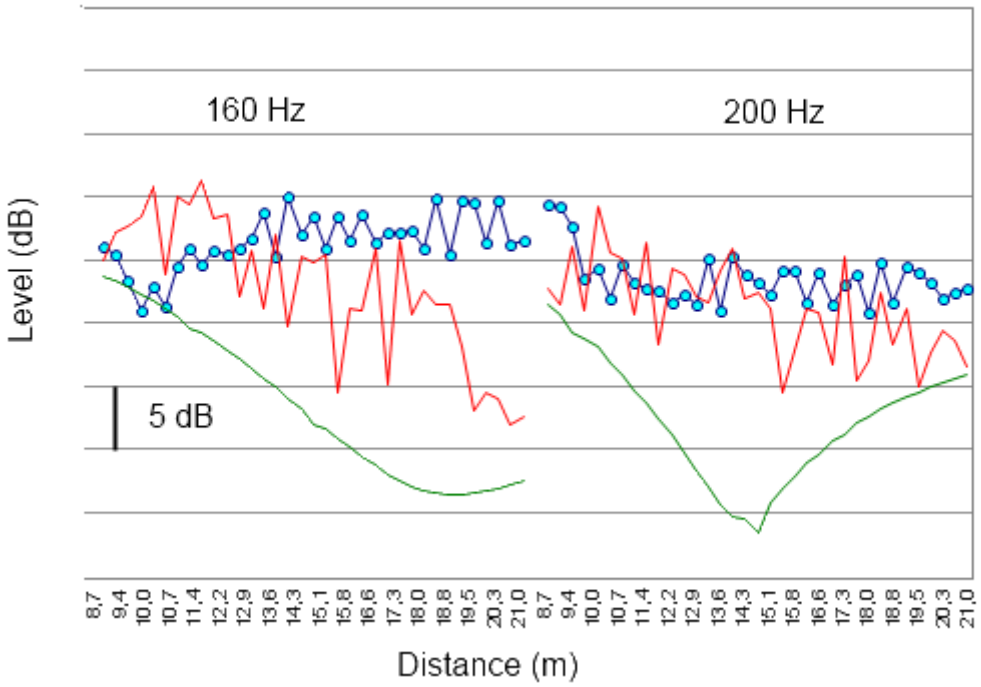
SPL vs Distance



EA vs Distance - 1/3 oct. bands

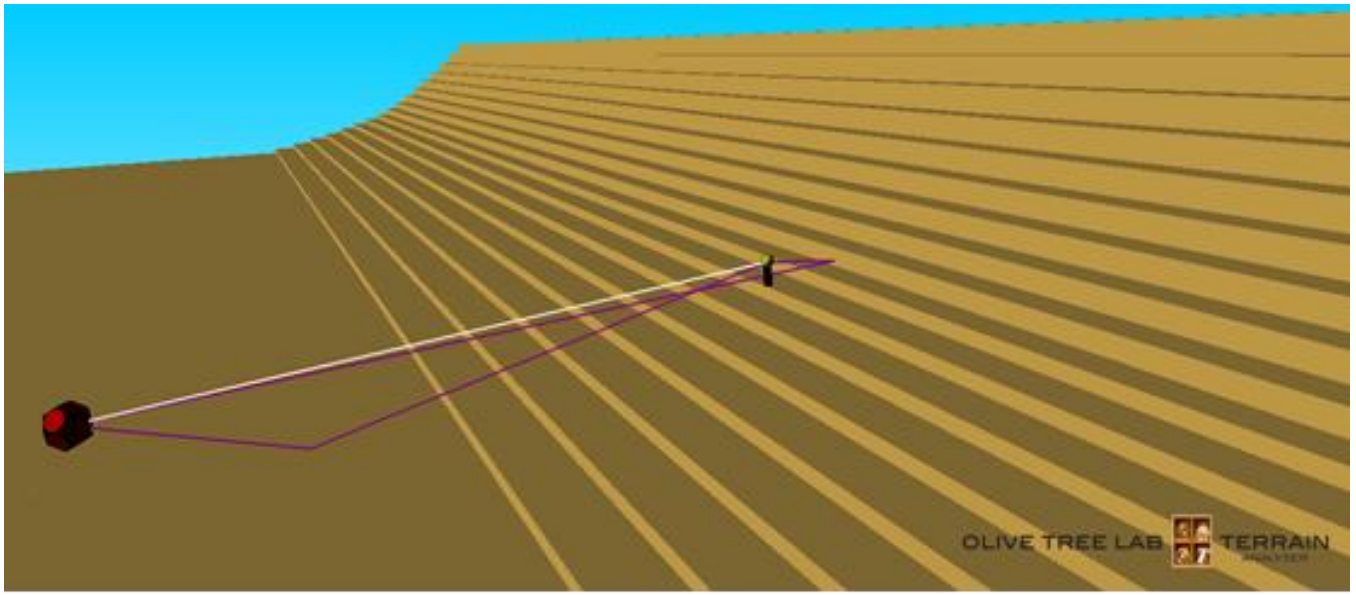


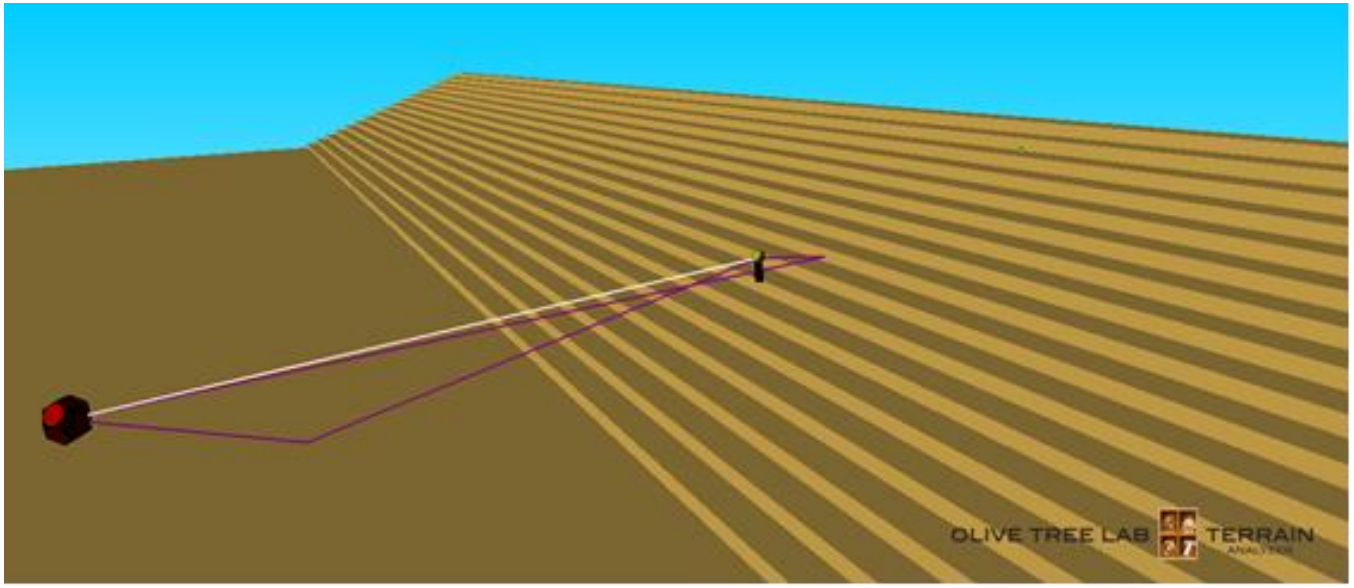
EA vs Distance - 1/3 oct. bands



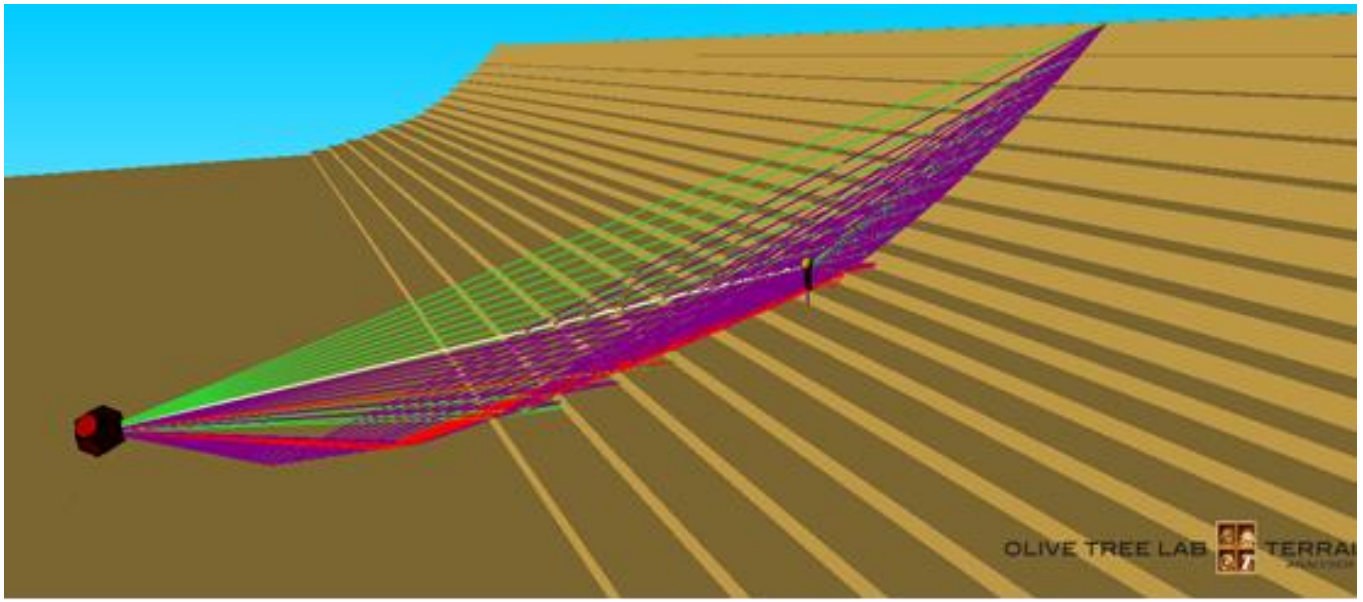
- Diffractions create a diffused field and compliment reflection effects.
- Sound predictions and simulations could come closer to real life sound fields provided they include sound diffraction effects.
- Diffractions are responsible for reverberation and the diffused field found in ancient theatres
- By not taking into account diffraction effects in simulations, there is the possibility of significant deviations from measurements…

2 identical Reflection paths for both theatres

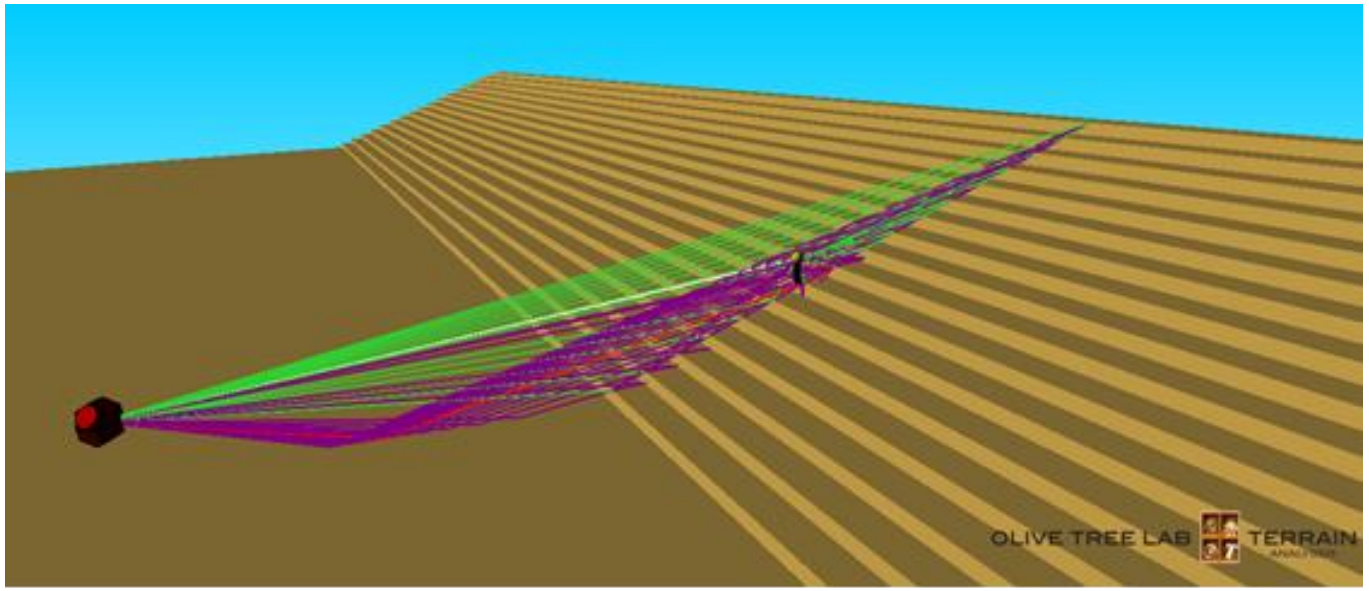




890 reflection & diffraction paths



529 reflection & diffraction paths



Finally…

- This is how a male speaker would sound like in the ancient theatre of Kourion (sample convolved with a measured Impulse Response)

Dry / Measured IR conv.

- This is how a male speaker would sound like in the ancient theatre of Kourion (sample is convolved with a simulated reflection only Impulse Response)

Dry / Reflections only Simulated IR conv.

Measured IR conv / Reflections only Simulated IR conv.

Anechoic speech sample is a courtesy of Patras University.

Thank you for your attention, we are ready for any clarifications