

# Investigating the Action of Complex Highway Noise Barriers by Means of the Finite Difference Time Domain Method and Sound Field Visualization

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## INTRODUCTION

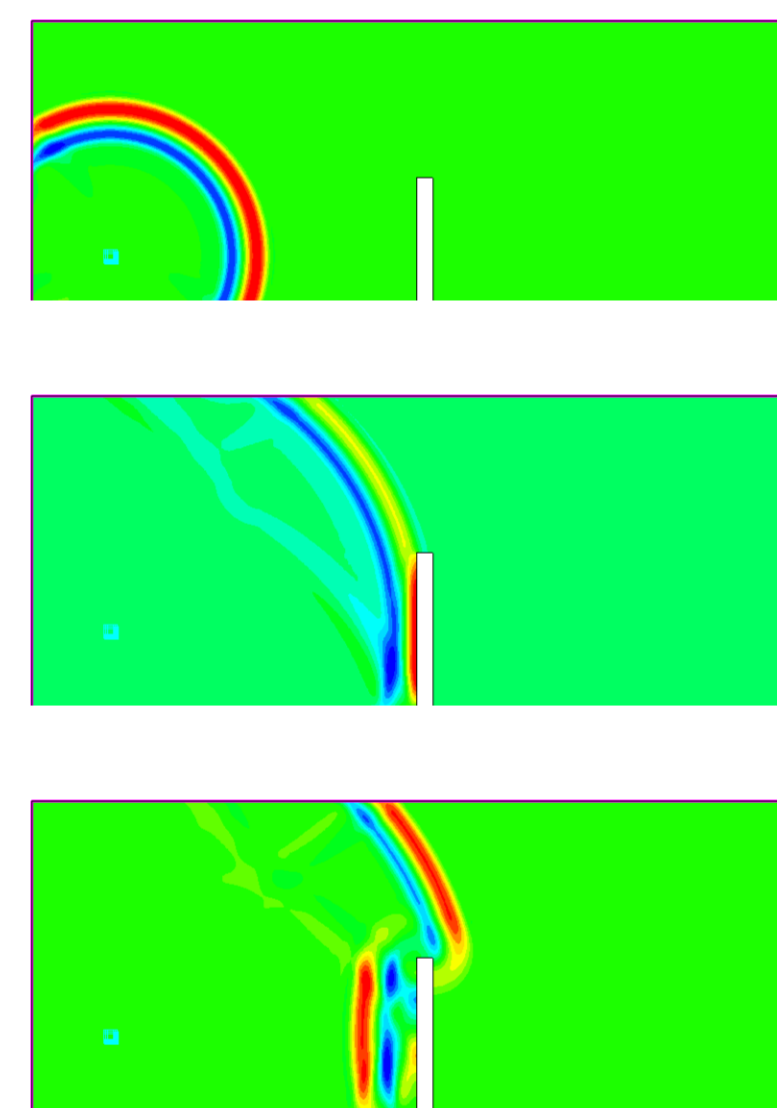
A basic barrier is a very simple device. However, its action becomes very complex when fitted with top edge modifications intended to enhance its acoustic performance. Various attempts to improve performance by top edge treatments have involved two basic approaches:

- Additional diffracting edges
- Impedance device at barrier top

As the dimensions of the added devices are comparable to the wavelength of audible sound it is not possible to predict their effect using analytical techniques and devices have been developed based upon a trial and error approach using physical scale models. It has been found that apparently very simple modifications to the design of a top edge treatment can drastically affect its performance. The lack of understanding of how the devices work has hindered their practical application. The EU sponsored Hollywood Project involves the application of numerical analysis using the finite difference time domain (FDTD) method. In the FDTD algorithm, the sound field is computed in discrete time steps and therefore transient acoustic phenomena can be easily animated. A transient acoustic pulse (sound of very short duration) enables the propagation of a sound to be visualised. In this way the interaction of the incident sound with the top edge device can be explored.

## SIMPLE BARRIER

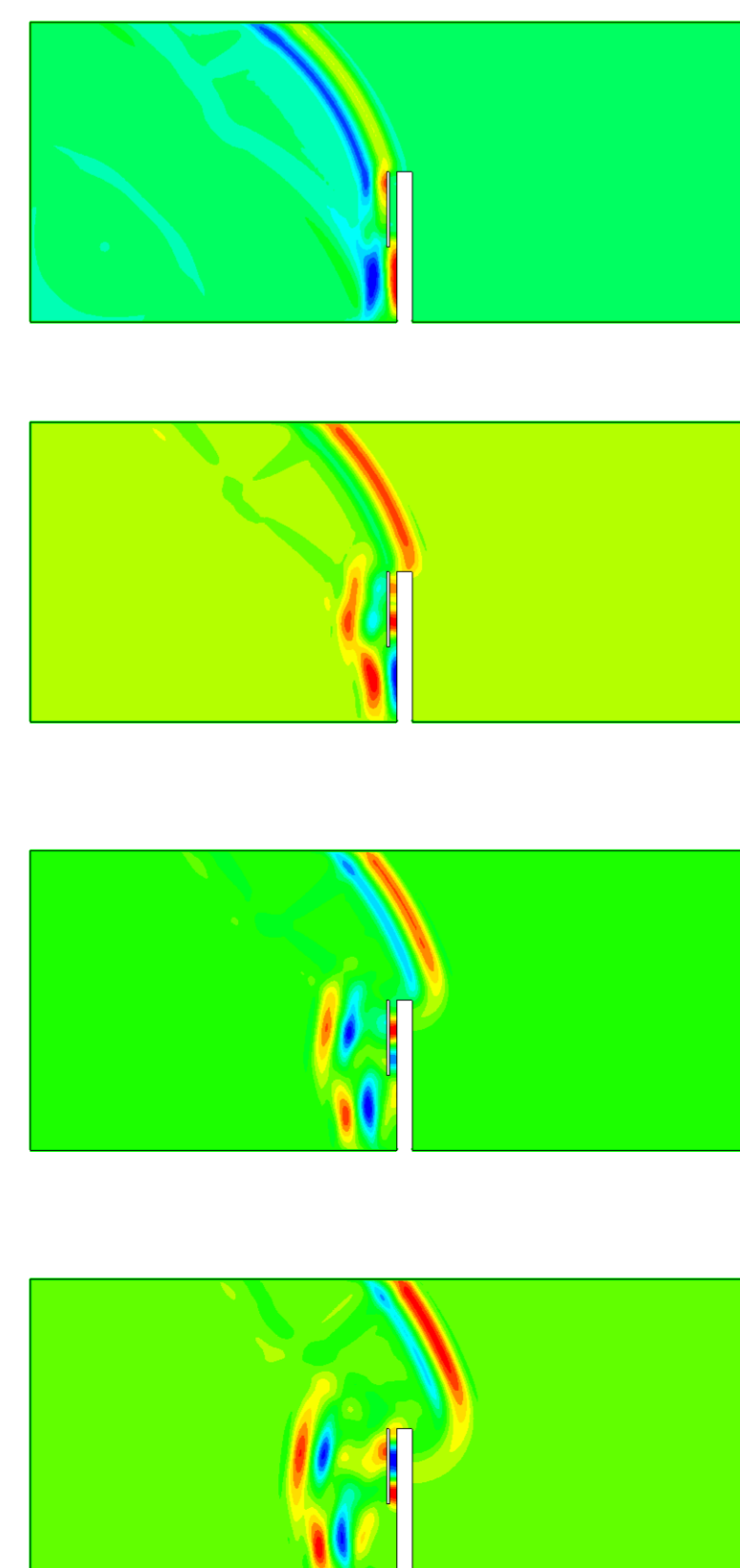
The following figures show the propagation of the transient wave as it encounters a simple barrier. It can be seen that most of the sound incident on the barrier is either reflected or continues to propagate away from the source. However, the diffraction of sound into the shadow region can be seen very clearly.



## ADDED EDGES

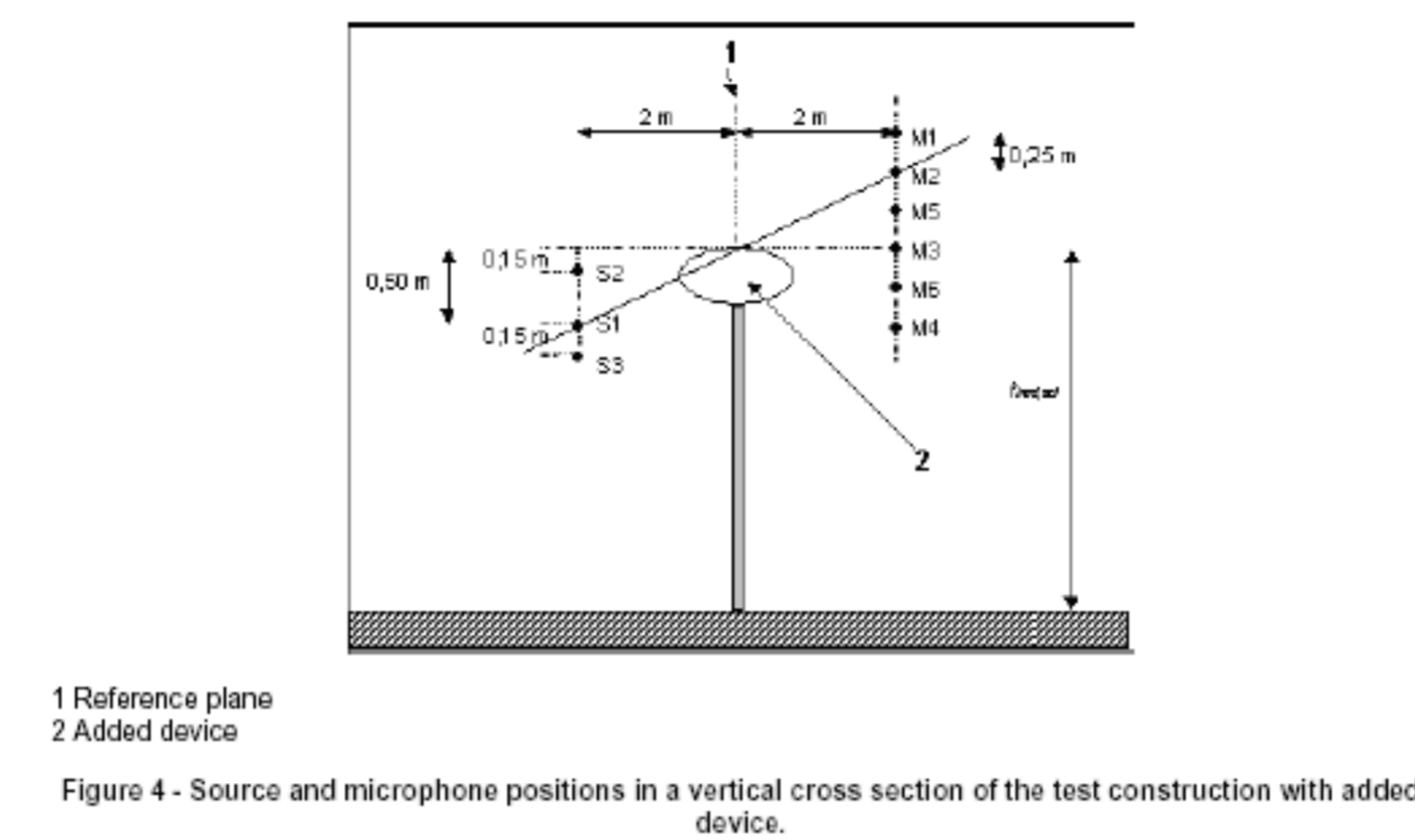
Additional edges have been proposed as a possible top edge modification. The underlying principle is again to provide additional diffracting edges. However, very different results have been obtained from measurements on such systems.

The figures illustrate what happens as sound reaches the barrier. Sound enters the gap between the barrier wall and the added edge from both the top and bottom openings. This gives rise to a resonance effect which enhances certain frequencies. Sound is radiated from the top of the gap and propagates into the shadow region.



## EXPERIMENTAL CONFIGURATION

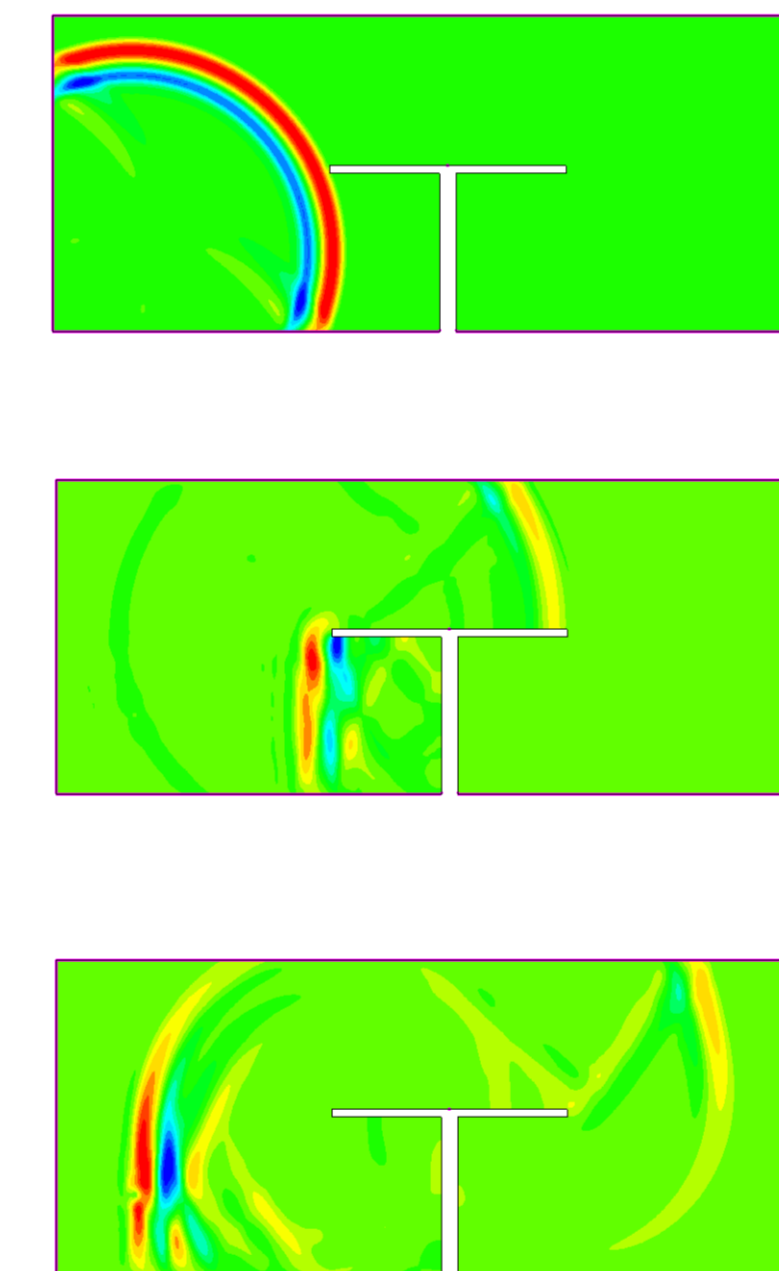
The performance of top edge devices has been studied using the ear field measurement configuration specified in CEN/TS 1793-4 Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 4: Intrinsic characteristics - In situ values of sound diffraction. This is illustrated in the diagram.



## T TOP BARRIER

One of the first attempts to enhance barrier performance was by the addition of a flat top giving the barrier a T shaped profile.

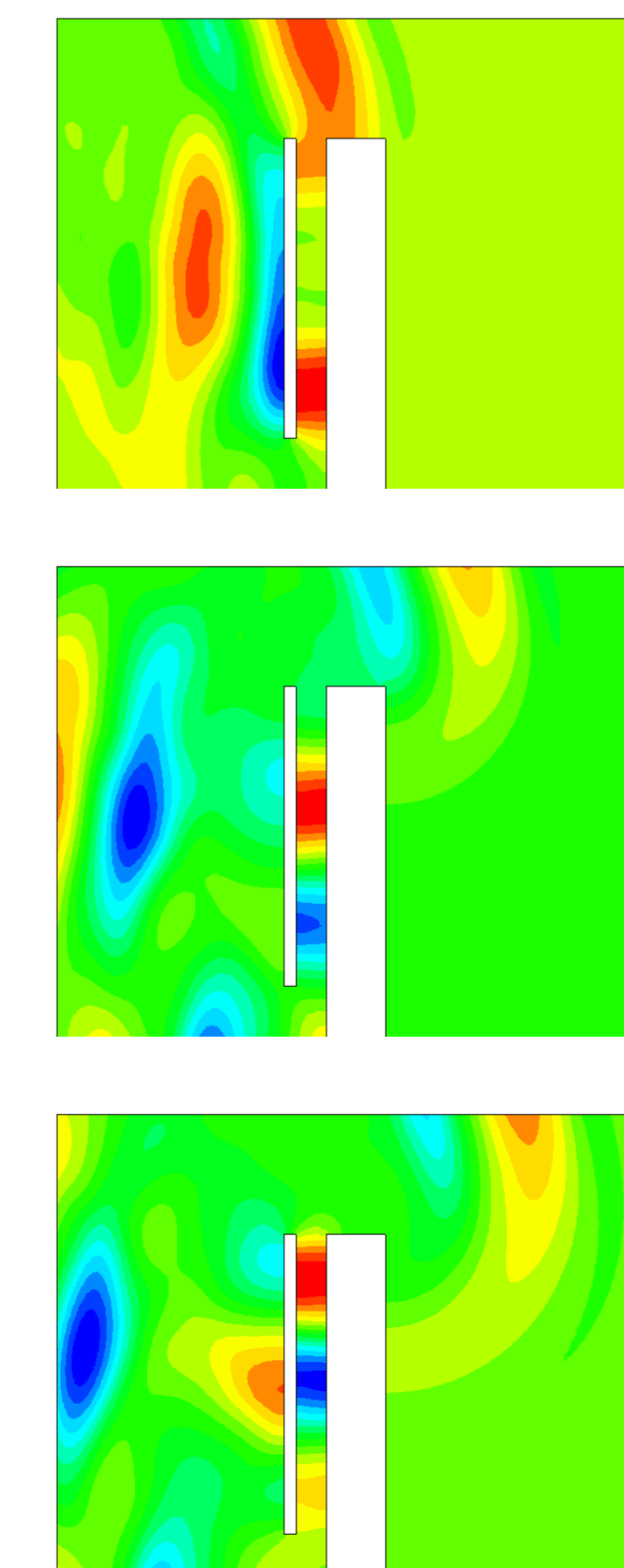
The underlying principle was that the added edge would provide additional diffraction and hence enhance screening. In practise it was found that the performance could be degraded at certain frequencies. The figures show the propagation of sound at a T top barrier. It can be seen that sound reflected from the vertical wall beneath the barrier can also be diffracted by the nearest edge of the T top.



## ADDED EDGE - NEAR FIELD

The ability to zoom into a particular region close to the active part of the barrier by means of a secondary mesh is particularly valuable for this type of top edge device.

As can be seen from the figures, the development of the sound field is very complex. Regions of very high sound pressure and of very low sound pressure can be observed which indicate a strong resonance effect.

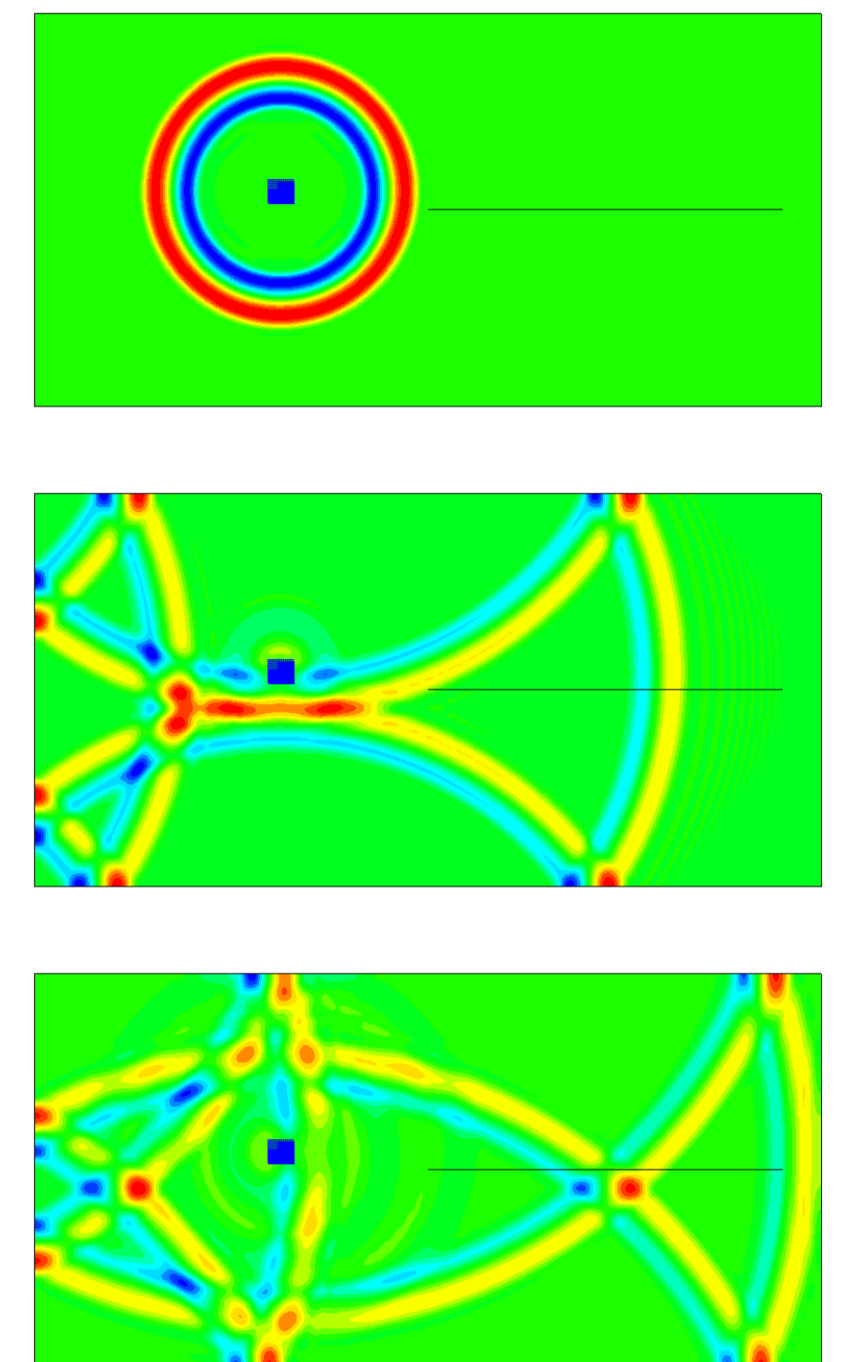


## SIMULATION BASICS

A sufficiently small sample interval is necessary so that the shape of the pressure wave (pulse) is very well defined. The same principle applies to the mesh size (consider the pressure wave as a function of distance).

A mesh size of 1cm and a sample interval of  $10^{-5}$  seconds have been employed. There are still problems of stability – as the pulse progresses it develops fluctuations which eventually take over. This can be overcome by adding damping by tweaking the constants in the mathematical method.

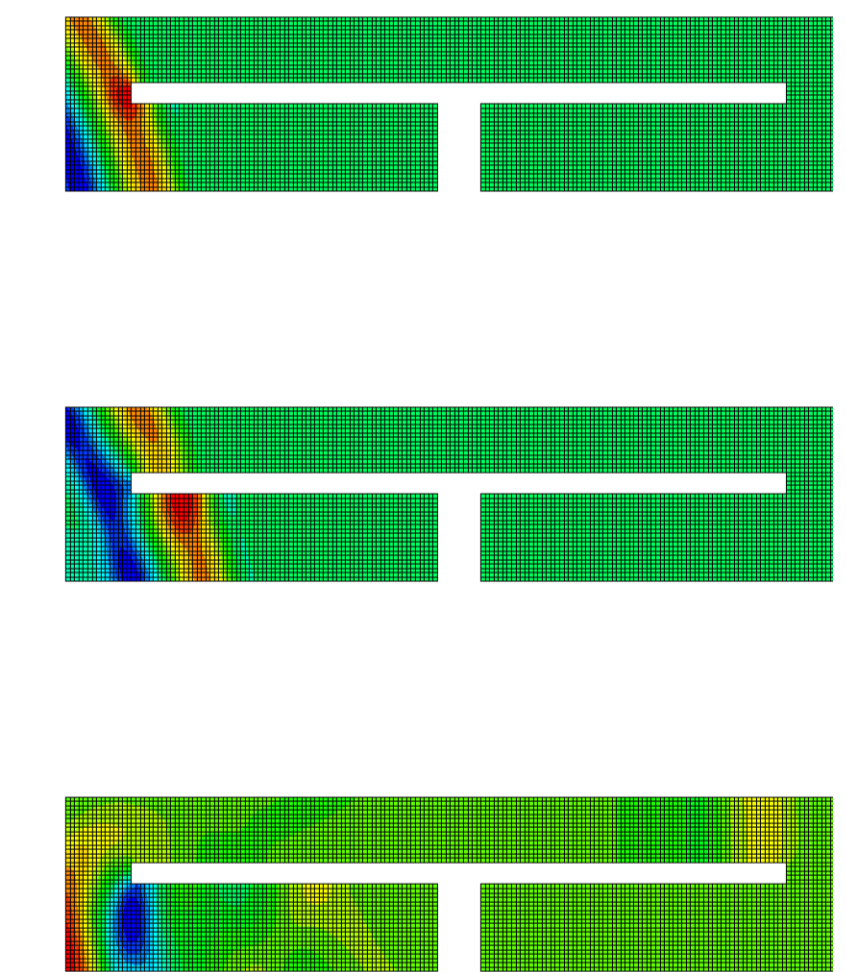
The following represents the development of a transient wave (sound pressure pulse) in a 2D room with reflecting boundaries and illustrate the quality of the resolution achievable. As time evolves there are interactions between the sound waves reflected at different surfaces giving rise to interference effects.



## T TOP BARRIER - NEAR FIELD

Although for the purpose of calculation it is necessary to mesh the volume of the test region, it is possible to employ a secondary mesh to zoom in on the region of most interest.

The figures show the near field details for the T top. It can be seen that at the barrier top sound energy propagates along both the top and bottom surfaces and that sound travelling in the lower region is reflected back towards the diffracting edge. At this point some of the reflected energy will propagate along the barrier top and be diffracted into the shadow zone. This sound will be delayed in time relative to the initial sound by a time interval determined by the dimensions of the T top and the velocity of sound. This delay will result in a degree of interference at a receiver location which may increase or decrease the sound level experienced at different frequencies.



## CONCLUSION

The visualization of a sound field can contribute greatly to the understanding the underlying mechanisms of various acoustic phenomena such as reflection, diffraction and interference and hence how they may be applied in the design of noise control systems. One acoustic device that has received a considerable amount of research attention is the highway noise barrier. A basic barrier is a very simple device but its action becomes very complex when fitted with top edge modifications intended to enhance its acoustic performance. Therefore, much of this research has been devoted to scale model and computer simulation studies of top edge strategies aimed at establishing their performance characteristics rather than studying how that performance is determined by complex wave effects in the vicinity of the devices.

This poster presents some examples of sound field visualization based on numerical analysis using the finite difference time domain (FDTD) method. In the FDTD algorithm, the sound field is computed in discrete time steps and therefore transient acoustic phenomena can be easily animated. The application of this technique to environmental noise control engineering involving the reflection and diffraction of sound around noise barriers with a variety of top edge configurations is investigated. It is shown that the visualization enables the most important aspects affecting the performance of the configurations to be identified.