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ACTIVE CONTROL OF HIGH FREQUENCY NOISE

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1. INTRODUCTION

Much of the current research on active noise control is confined to restricted spaces such as earphones, active silencers, air-conditioning ducts, truck cabins and aircraft fuselages. A theory that explores the basic concepts of environmental noise reduction using active noise control on compact sources in unconfined spaces has recently been published in the EJR Memorial Edition of JSV [1]. A second paper on non-compact acoustic sources has also been submitted to JSV. This present paper highlights the basic cancellation properties of non-compact free field sources. The work is sponsored by EA Technology and Yorkshire Electric in United Kingdom. Figure 1. illustrates the geometry of the cancelling system.

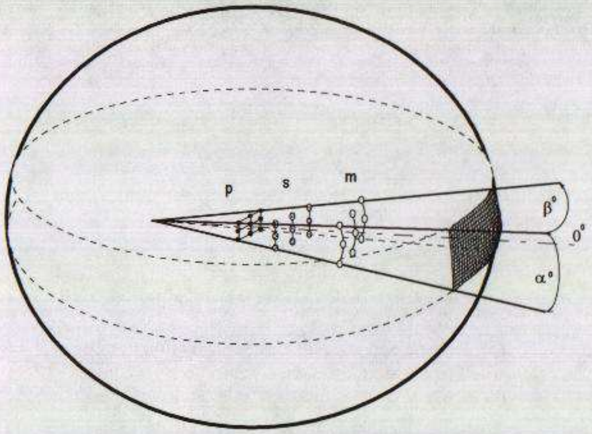

Figure 1. 3D View on Primary, Secondary and Microphone Arrays Controlled within Angles α and β, also Showing 360°×15° All-round Observer Strip

2. COMPUTED ACOUSTIC SHADOWS

Figure 2 shows the resulting 400 Hz (λ=0.858 m) shadow from a primary D=2 m square source giving a compactness factor, λ/D= 0.429. The shadow is generated by a 9×3 array of discrete secondary sources (cancellers) equispaced over a 60°× 15° control angle giving a secondary source separation distance d=D/N-1=1 m, where N=3 is the number of secondary sources in a column, giving a discreteness factor λ/d=0.858. The cancellers are positioned at a primary source - canceller distance of r_s=1.715 m (2λ). A matrix of 9×3 monitoring microphones are equispaced within the control angle positioned at 50 m from the primary source. The "continuous" primary source distribution is represented by p=40×40=1600 equispaced inphase discrete sources giving a primary source separation distance of d=2/39=0.051 and a discreteness factor of λ/d=16.8. The phase and amplitude of the cancellers are optimised to give minimum collective sound pressure at the microphones, using the method of least squares. Further details of the shadow generating process can be found in reference [2] and [3].

The resulting shadow in dB contours for a 360° observer strip around the primary source, and 60° in elevation is shown in the top of the figure. In the lower figure the sound pressure averaged across the 15° elevation control angle is given. The dotted curve shows the uncancelled field with a maximum centre SPL of 108 dB and a first zero at approximately $\theta_{z1}=\sin^{-1}\lambda/D$=25°. As can be seen the resulting shadow is 50 dB and has no problem traversing the complex field including a phase reversal.

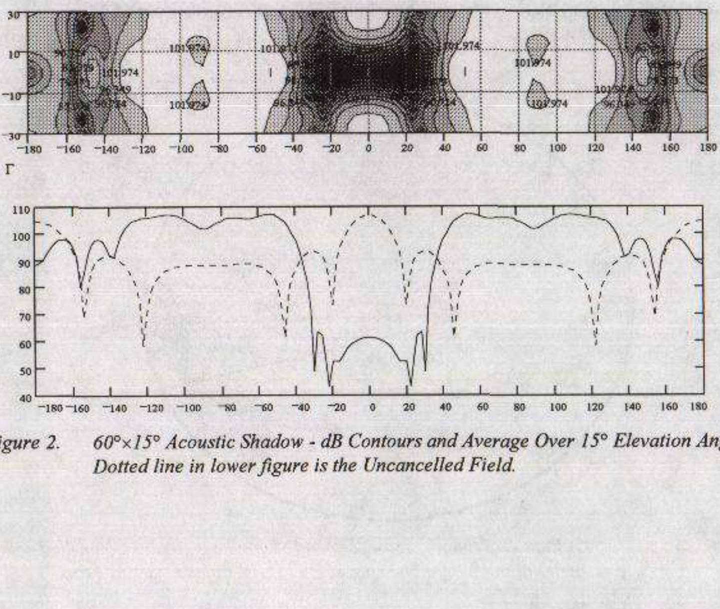

Figure 2. 60°×15° Acoustic Shadow - dB Contours and Average Over 15° Elevation Angle. Dotted line in lower figure is the Uncancelled Field.

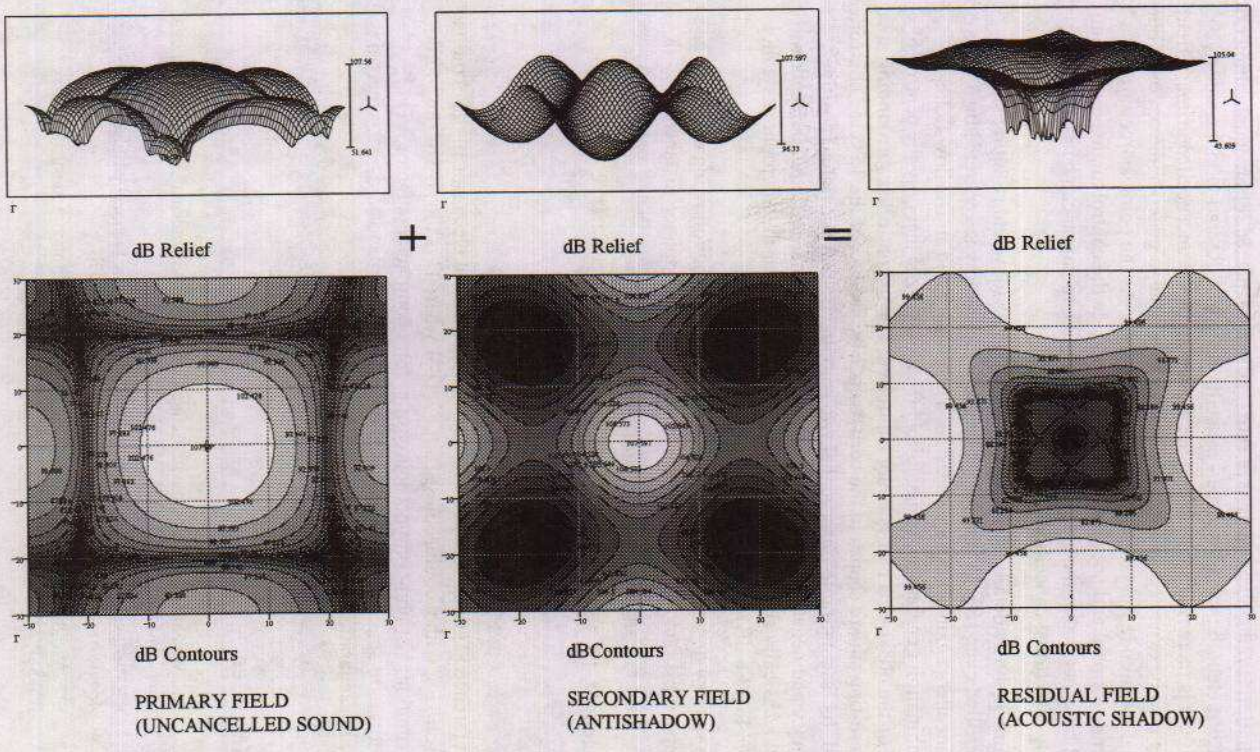

Figure 3. Generating 400 Hz Shadow

Radiation is reduced to the rear (±180°), as to be expected for an equal number of half wavelength primary source - canceller distances. Radiation to the side ±(20° to 160°) is increased approaching the maximum of the uncancelled primary field. This is to be expected as the cancelling sources have to generate the opposite but equal magnitude field to cancel the primary field. As the point sources are omnidirectional and not phase coordinated outside the control angle equal sound will be generated to the side. Increases in the side radiation can be avoided by using directional cancelling sources.

Figure 3. shows details of the primary field, antishadow and resulting shadow controlled over 15°×15° angles. In this case the shadow is generated by 3 rows of 3 cancellers again giving a λ/d=0.858. The primary and antishadow fields in combination generate the residual field (shadow). Note that only the centre 15°× 15° of the 60°×60° sector is being controlled. The uncontrolled surrounding area (interesting square shapes in the corners) is a by product of the 15°×15° controlled field. Its fascinating to observe that two smooth circular like fields (positive primary and negative secondary) produce a residual sharp rectangular shadow with a basically flat bottom (apart from low values near the microphones going down to 43.6 dB)

The shadow depth in dB, is given approximately by the following equation for a compactness factor λ/D=0.429 and observer and microphone distance of 50 m.

$$dB=-n\log 2\lambda/d$$

where n=9, 13, 16 for $r_s=8\lambda$, 2λ, $\lambda/2$ respectively.

3. CONCLUSIONS

In reference [1] deep acoustic shadows were generated electronically for compact sources, i.e. with a compactness factor λ/D>1 where D is the size of the source distribution. For non-compact sources i.e. for a compactness factor λ/D<1, shadows are again obtained provided the discreteness factor λ/d>0.5, where d is now the separation distance between cancellers.

References

[1] S.E. Wright and B. Vuksanovic, Active Control of Environmental Noise, *Journal of Sound and Vibration,* 190(3), 565-585, (1996).

[2] S.E. Wright and B. Vuksanovic, Active Control of Low Frequency Noise *Acoustica (Forum Acusticum Proc.)*, 82, 196, April 1996

[3] S. E. Wright and B. Vuksanovic, Optimisation of Controlled Acoustic Shadows, ICASSP Atlanta, AE 2-9 May 1996