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AN IMPROVED SOURCE MODEL FOR AIRCRAFT
INTERIOR NOISE STUDIES

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Abstract

There is concern that advanced turboprop (ATP) engines currently being developed as an alternative to turbofan engines may produce excessive aircraft cabin noise levels. This concern has stimulated renewed interest in developing aircraft interior noise reduction methods that do not significantly increase take-off weight. Both synchrophasing and active control of interior noise have been proposed as solutions, but neither has been perfected, mostly because of a lack of physical understanding of the sound transmission mechanism.

The present paper exploits an existing analytical model for noise transmission into aircraft cabins to investigate the behavior of an improved propeller source model for use in aircraft interior noise studies. The new source model, a virtually rotating dipole, is shown to adequately match measured fuselage sound pressure distributions, including the correct phase relationships, for published data. As an example of its application, the virtually rotating dipole is used to study the sensitivity of synchrophasing effectiveness to the fuselage sound pressure trace velocity distribution. Results of calculations are presented which reveal the importance of correctly modeling the surface pressure phase relations in synchrophasing and other aircraft interior noise studies.

N85-17668#

Nomenclature

a	Shell radius, m
A, B	Complex pressure amplitudes at radius r from dipole sources, Pa
c	Speed of sound in air, m/s
c_L	Extensional phase speed of shell material, m/s
d	Spacing between monopoles defining a dipole, m
f	Frequency, Hz
i	$\sqrt{-1}$, -
L	Spacing between microphones, m
ℓ	Vertical distance from $\theta = 0$ to midpoint between two microphones, m
p	Complex acoustic pressure, Pa
R	Radial position of compact source with respect to shell centerline, m
R_p	Propeller radius, m
r	Radial position with respect to compact source; also, radial position on shell interior, m
T	Period of rotation of virtually rotating dipole, s
t	Time, s
v_t, v_t'	Trace velocity, m/s
x	Axial position along fuselage, m
α	Angle subtended at propeller hub by distance between microphones, r
θ	Angular position in shell coordinates, r
μ	Angle defined by Eq. (5) and in Fig. 3, r
ϕ	Phase angle, r
ψ	Angular position in source coordinates, r

Ω Propeller rotational speed, RPM

ω Angular frequency, r/s

Subscript and Superscripts

R Refers to real component

exp Refers to experimental result

th Refers to theoretical result

Introduction

Advanced turboprop (ATP) engines are currently under development as an alternative to turbofan engines for transport aircraft. The ATP is attractive because it offers the possibility of significant increases in fuel efficiency without an unacceptable sacrifice of flight speed. However, a serious disadvantage of the ATP is the inherent high noise level associated with its supersonic tip speed. This raises concern that the ATP engine may produce excessive cabin noise levels. The problem is aggravated by the fact that the dominant frequency of the noise produced by the ATP is expected to be low, thus rendering passive methods of noise control relatively ineffective. It is even conceivable that much of the fuel efficiency gained from use of the ATP engine would be lost because of the weight penalty associated with the addition of mass and absorptive materials needed to limit sound transmission through the cabin wall. Hence, there has been a concerted drive to develop a successful interior noise reduction method that does not significantly increase take-off weight.

Two promising techniques for aircraft interior noise reduction which do not increase take-off weight are synchrophasing [1,2] and active control of interior noise [3]. Although both methods have shown some success, their application to real aircraft has been severely hampered by a lack of physical understanding of the transmission mechanisms. A "cut-and-try" approach has generally been used in the past.

Fuller [4] has recently developed an analytical model for noise transmission into aircraft cabins. The model, which is based on an explicit closed form solution of the equations describing the structural response of an infinitely long, submerged, fluid-filled cylindrical shell to an arbitrary distribution of monopole sources exterior to the shell, has been used successfully to reveal and explain the controlling mechanisms behind the synchrophasing concept. The cylindrical shell is assigned properties typical of an aircraft fuselage, and the propeller noise sources are modeled as acoustic dipoles. The use of an infinitely long cylinder is justified by measurements which show that the propeller-driven fuselage vibration levels and the concomitant interior sound field decay with axial distance from the propeller plane. The details of the analysis are given in Ref. 4, and so only its essential elements are outlined here.

First, expressions are written for the Fourier transforms of the shell displacements, the interior acoustic field, and the pressure at the exterior surface of the shell due to a single exterior acoustic monopole. These expressions are then substituted into the equations of motion for a fluid-loaded cylindrical shell to obtain the spectral equations of motion for the forced response of the system to a single exterior monopole source. The resulting equations are then solved in closed form using standard matrix techniques, and the results inverse Fourier transformed to obtain explicit expressions for the radial displacement of the shell and the interior and exterior acoustic pressure fields. The response of the system to an arbitrary distribution of monopole sources, in which each source generally has a different phase and strength, is then obtained by linear superposition of the results for the individual monopoles.

In Ref. 4, Fuller chose to model the propellers on either side of the twin-engine aircraft as dipoles whose axes are oriented toward the fuselage. This source model allows the directivity and strength of the sources to be adjusted to approximate the pressure distributions typical of those observed on actual aircraft fuselages. Variation of the phase angle between propeller blades moving past the fuselage on either side of the aircraft can be simulated by varying the phase relationship between the two dipoles. This angle is called the synchrophase angle. Fuller found that there was an optimum synchrophase angle that minimizes the sound pressure level at each interior location. Reductions on the order of 10-15 dB were predicted at typical locations in the cabin. Jones and Fuller [5] also conducted experiments in which a long aluminum cylindrical shell suspended in a large anechoic chamber was driven by acoustic monopoles positioned on either side of the shell. They obtained synchrophasing results that are in remarkable agreement with the predictions in Ref. 4.

Fuller's aircraft interior noise model is significant because, although based on a rather simple physical model, it nonetheless contains all of the essential features needed to understand interior noise transmission mechanisms such as synchrophasing. Because it involves an explicit closed form solution of the governing equations, the physics is not obscured by a complex computer code, as is often the case when purely numerical techniques are used to obtain solutions to structural dynamics problems. While not directly formulated for predicting interior noise levels in actual aircraft, it is very useful for studying the physical mechanisms as well as the effects of parameter variations involved in the transmission of sound into aircraft cabins.

One of the significant advantages of Fuller's model is that the source field is built up from individual monopoles. Appropriate propeller source fields can easily be synthesized based on, for example, sound pressure distributions measured on the exterior surface of the fuselage. While the analytical model has proved successful in certain applications, the work of Piersol, et al. [6] suggests that circumferential trace velocity effects can strongly influence the transmission of sound into the cabin. The trace velocity is defined here as the velocity with which an acoustic wave sweeps across the fuselage surface. This trace velocity influence occurs because the response of the fuselage is related to the complex pressure distribution (magnitude and phase) rather than just its absolute value. Fuller's original model does not include trace velocity effects; thus, it was the aim of the present effort to develop a source model which produces surface trace velocity and pressure distributions similar to those observed on the fuselage of an actual turboprop-powered aircraft. As an example application of the new model, it is used to re-examine aspects of the previously studied synchrophasing situation.

The Virtually Rotating Dipole

We have used Fuller's aircraft interior noise model in conjunction with published data [6] to synthesize a source model which, although still relatively simple, nevertheless models all of the essential features of the measured propeller-generated sound pressure field on the fuselage. This new source model, which is the subject of the present paper, thus permits consideration of interior noise problems under more realistic conditions.

The fuselage sound pressure data from Ref. 6 were measured using flush-mounted microphones distributed as shown in Fig. 1. Because the local pressures were recorded simultaneously on a multichannel recorder, it was possible to recover relative phase relationships between pairs of microphones at any given frequency. It was found that the measured phase angles between pairs of microphones in the propeller plane, numbers 3, 4, 5, and 6 in Fig. 1, correspond to a subsonic trace velocity,

$$v_t = \omega L/\phi \quad , \tag{1}$$

where ω is the frequency in radians per second, L is the microphone spacing in meters, and ϕ is the measured phase angle in radians. In fact, the authors of Ref. 6 found that the trace velocities given by Eq. (1) could be predicted to within a few per cent by assuming a "rigid body" pressure field rotating with the propeller and using the corresponding relation

$$v_t' = 6\Omega L/\alpha \quad , \tag{2}$$

where Ω is the propeller rotational speed in RPM and α is the angle in degrees subtended at the propeller hub by the distance L between microphones. This makes it clear that the corresponding source model for use in Fuller's interior noise model should exhibit the observed rigid body rotation.

The simplest compact source which provides the required virtual rotation is a pair of equal strength dipoles located in the propeller plane whose axes intersect at right angles and which are 90 deg out of phase with each other, as shown in Fig. 2(a). If counterclockwise rotation is desired, then each of the four monopoles must lag its clockwise neighbor by 90 deg. That is, monopole number 1 must lag monopole number 2, which in turn must lag number 3, and so forth. While the monopoles themselves remain motionless, they will produce a combined dipole-type directivity pattern which rotates in the counterclockwise direction with an angular velocity equal to the angular frequency of oscillation of the dipoles. That this is true can be demonstrated by considering how the individual free-field directivity patterns combine at any instant in time. Consider the point P at fixed radius r and arbitrary angular position ψ in the plane of the dipoles in Fig. 2(a). The acoustic pressure at any instant at this point will be the sum of the contributions from the two dipoles,

$$p(\psi,t) = A\cos(\psi)\,e^{i\omega t} + B\cos(\psi-\pi/2)e^{i(\omega t+\pi/2)}. \tag{3}$$

The complex coefficients A and B are themselves functions of r and ω, but since r and ω are constant in the context of this discussion of directivity, A and B may be considered to be complex constants. Then if the two dipoles have the same strength, A = B and Eq. (3) reduces to

$$p(\psi,t) = A\ e^{i(\omega t+\psi)}. \tag{4}$$

Thus, the rms directivity pattern is circular with its center at the intersection of the axes of the two dipoles. Further, at each instant in time, the pattern is periodic in ψ, so that instantaneously the usual dipole double-lobed pattern exists with an orientation which depends on t, as shown in Fig. 2(b).

It should be emphasized that the rotation of the directivity pattern through one cycle does not represent one rotation of the propeller; rather, it represents one cycle of the fundamental, or a harmonic, of the complex sound pressure field produced by the motion of an individual propeller blade past the fuselage. This interpretation is suggested by the success of Eq. (2) in predicting the experimentally observed circumferential trace velocities. The fuselage acoustic pressure field, at least in the propeller plane, is evidently dominated by the alternating high and low pressures, associated with the "frozen" propeller blade pressure distributions, which are swept across the fuselage with the passage of each individual propeller blade.

It has already been suggested that the virtually rotating dipoles should be located in the propeller plane, since they represent the propeller source. Their radial position with respect to the fuselage centerline can be estimated from knowledge of the axial trace velocities, once again computed using Eq. (1). From Fig. 3 it is clear that the axial trace velocity is related to the acoustic velocity in air, c, according to

$$v_t = c \sec \mu \quad . \tag{5}$$

Equations (1) and (5) provide a basis for drawing lines extending from the midpoint between a pair of the microphones, numbered 1, 2, 5, 7, and 8 in Fig. 1, to their intersection with a line representing the propeller plane. This intersection provides a one-dimensional estimate of the source location. It is noted that convective effects, which might influence the trace velocity for the microphones downstream of the propeller, have been ignored in constructing Fig. 3. These effects are expected to be minimal in this case because the data are from stationary operation of the aircraft and the propeller backwash is highly subsonic.

The radial position of the virtually rotating dipole sources could have also been established from the circumferential trace velocities, in which case they would be located at the propeller hub. However, the axial trace velocities were used instead for three reasons. First, propeller radiation theory suggests that the source activity increases going from the hub to the tip. Next, Fuller's interior noise theory makes it clear that the most important propeller sources for cabin interior noise production are those nearest the fuselage. Finally, and perhaps most importantly, the best agreement between measured and predicted fuselage surface sound pressure distributions are obtained with the source at a position corresponding to about 60 per cent of the propeller hub-to-tip distance.

Synthesis of the Equivalent Propeller Source Model

Figure 4 shows the equivalent propeller source model synthesized from the data of Ref. 6. The virtually rotating dipole sources are centered at R = 1.55a, where a is the equivalent fuselage radius, 0.71 m, of the test aircraft. The fundamental frequency in this case is 66.7 Hz and the material is aluminum with an extensional phase speed c_L of 5150 m/s, which corresponds to $\omega a/c_L = 0.057$. The propagating medium is air with c = 343 m/s. As pointed out in connection with the discussion of Fig. 3, the radial position of the source corresponds to a location in the propeller plane about 60 per cent of the distance from the propeller hub to its tip. The spacing between the monopole sources which make up the dipole is 0.1a. This configuration automatically reproduces the measured axial trace velocities because the value of R/a was selected based on them, as explained above.

As the source directivity pattern rotates, let ϕ be the instantaneous angle its axis makes with respect to an arbitrary reference in source-centered coordinates. Further, let the extension of this axis intersect the fuselage at angle θ in fuselage-centered coordinates. Then, in keeping with the idea from Ref. 6 that the circumferential trace velocity is tied to the motion of the individual propeller blades past the fuselage, a theoretical trace velocity can be computed as

$$v_t^{th} = a\ d\theta/dt \quad , \tag{6}$$

where $d\theta/dt$ is related to θ and ω (= $d\phi/dt$) by the geometry. It is noted that this theoretical trace velocity ignores scattering from the fuselage as well as possible near field effects. For example, the trace velocity defined in this way does not take into account the phase variation with θ due to radial propagation from the compact source. It is uncertain at this time how these additional complexities affect the circumferential trace velocity, but it seems likely that effects associated with the geometrical differences between the actual and model fuselages will be at least as important. Therefore, although this question is the subject of continuing research, its resolution is not critical to the present study.

Table I gives the ratio of the theoretical circumferential trace velocities, computed using Eq. (6), to the corresponding measured values from Ref. 6. The circumferential position θ in Table I is defined as

$$\theta = \tan^{-1}[\ell/a] \quad , \tag{7}$$

where ℓ is the vertical distance from the $\theta = 0$ plane to the midpoint between the two microphones in question. The deviation of the theoretical-to-experimental trace velocity ratio from unity is attributable to two departures of the model from reality whose effects conveniently tend to cancel each other. First, the experimental trace velocities, given by Eq. (1), were shown in Ref. 6 to agree with values predicted using the rigid body rotating pressure field model, Eq. (2), to within a few per cent. However, the actual propeller hub is located at $R = 2.83a$, while the source model is located at $R = 1.55a$. Thus, if the fuselage in the model situation had the same rather rectangular shape as the actual fuselage, the trace velocity ratio would be about $0.55/1.83 = 0.30$, depending only slightly on the angle θ. The second departure from reality is the difference in shape between the actual fuselage sidewall, which is relatively flat, and the model fuselage sidewall, which is cylindrically convex. Of course, it is not possible to exactly model trace velocities measured on a flat surface using a single compact source radiating to a cylindrically convex surface, because the trace velocity in the latter case varies much more strongly with θ than in the former case. In view of this, the agreement actually obtained between the calculated and measured circumferential trace velocities, especially for small θ where the forcing function is largest, is gratifying.

Figures 5 and 6 compare the measured fuselage sound pressure distribution from Ref. 6 with the distributions predicted on the basis of Fuller's model, for both the simple dipole and virtually rotating dipole source models. Results are shown for the fundamental and first four harmonics of the sound pressure spectrum. The curves for each harmonic order have been normalized by the corresponding value of pressure measured at $x/a = 0$ and $\theta = 0$.

The asymmetry in the measured circumferential pressure distributions, Fig. 5, is due to the shape of the fuselage wall (see Fig. 1). The theoretical distributions, which are for a cylindrical fuselage, are necessarily symmetrical about $\theta = 0$, and thus cannot exactly match the measured distributions. The shape of the actual fuselage is such that the theoretical distributions, which are normalized to the measured values at $\theta = 0$ for each harmonic, tend to overpredict the measured distributins for $\theta < 0$ and underpredict them for $\theta > 0$. The theoretical results for both types of source model are in adequate agreement with the measured values in view of the geometrical differences between the modeled and actual fuselages.

The asymmetry in the measured axial pressure distributions, Fig. 6, may be at least partially attributed to convective effects downstream of the propeller. Even though the data were obtained for static operations, the propeller backwash could reasonably be expected to exert some influence on the downstream (negative values of x/a) pressures. The agreement between the measured and predicted distributions is generally quite good, with the major deviations occurring when individual measurements suffer large departures from the overall trend for a given harmonic order. Recall that the main goal of this work is to synthesize a source, suitable for use in Fuller's closed form analysis, that models the observed trace velocities. Then any agreement that the resulting source gives between predicted and observed measured surface pressure magnitudes, especially in the region of the propeller tip's closest approach to the fuselage, represents a substantial improvement over the simple dipole source model since this latter cannot account for circumferential trace velocities.

Table I and Figs. 3, 5, and 6 all indicate that the essential features of the fuselage surface sound pressure distributions, observed in the neighborhood of the point of nearest approach of the propeller tip to the fuselage, can be modeled using the virtually rotating dipole of Fig. 4, at least for the aircraft of Ref. 6. An important conclusion of Fuller's earlier synchrophasing study [4] is that interior noise is dominated by the interaction between the fuselage and the propeller radiation field in the region within one or two fuselage radii of the propeller plane. Thus, the proposed propeller source model seems well suited for use in future aircraft interior noise studies.

Sensitivity of Synchrophasing Behavior to Source Model

Now that a spectral propeller source model has been identified which exhibits the essential radiation characteristics of an actual propeller at a given frequency, it is interesting, as an example application, to see how synchrophasing results obtained using this model differ from those obtained using the simple dipole model. Figure 7 shows the variation with synchrophasing angle of the relative attenuation of sound pressure at a point on the cabin interior surface ($r/a = 1.0$), in the propeller plane ($x/a = 0.0$), at an angle of $\theta = \pi/4$, for the two source models. The dimensionless frequency, $\omega a/c_L$, in this case is 0.2. It is clear from this figure that there can be a very significant difference between the synchrophasing effectiveness predicted using the two source models. While the simple dipole source predicts a very strong maximum attenuation at a synchrophasing angle of about 310 deg, the virtually rotating dipole source predicts a much smaller maximum attenuation at a synchrophasing angle of about 75 deg.

Smaller attenuation is generally obtained with the virtually rotating dipole source because shell modes are excited which are not present for simple dipole excitation. As Fuller points out in Ref. 4, for infinite attenuation it is necessary that only odd or even modes be individually generated, in which cases the optimum synchrophase angle is 0 deg or 180 deg, respectively. Thus, when additional monopoles are introduced at differing source angles, as in the case of the virtually rotating dipole, there is a corresponding increase in the broad band response of the shell (in a circumferential modal sense). The result is a significant drop in the amount of attenuation available, and a change in the optimum synchrophase angle. It may then be inferred that the differences between the simple dipole and virtually rotating dipole results shown in Fig. 7 occur as a result of changes in the phase of the interior sound field associated with each source rather than as a result of changes in the magnitude. Since the two types of source produce nearly the same distributions of fuselage pressure magnitude, yet yield significantly different synchrophasing results, it can be inferred that the synchrophasing effect is very sensitive to the surface sound pressure phase relationships represented by trace velocities. In other words, it is the complex pressure distribution on the fuselage surface which is important rather than just absolute values.

Calculations show that the most significant differences between the synchrophasing behaviors produced by the two source models occur at the interior point represented by Fig. 7. By way of contrast, the two source models produce exactly the same relative attenuation curves at all values of x/a and r/a when $\theta = 0$, which is the plane of symmetry of the vertical element of the virtually rotating dipole.

Figure 8 shows the variation with synchrophase angle of the relative attenuation of sound pressure at a point in the propeller plane near the cabin centerline ($r/a = 0.1$, $x/a = 0.0$, $\theta = \pi/4$), once again at $\omega a/c_L = 0.2$, for both source models. Because this point is near the $\theta = 0$ plane (which includes the centerline), the deviation between the relative attenuation curves for the two source models is not as great as in Fig. 7. However, the difference is still significant.

Conclusions

A new spectral propeller acoustic source model for aircraft interior noise studies has been synthesized based on experimental results from the literature and dipole radiation theory. The model gives good agreement with observed fuselage sound pressure magnitude and phase distributions in the neighborhood of the propeller. When the source model is used to predict interior noise attenuation by synchrophasing, the results differ, sometimes significantly, from those obtained using a simple dipole source model.

The principal conclusions which can be drawn from this study are:

(1) synchrophasing results are sensitive to the source model used, and thus

(2) correct modeling of the fuselage surface trace velocities is important in aircraft interior noise studies.

The virtually rotating source model described in this paper provides reasonable approximations of both the magnitude and phase angle distributions of the fuselage surface sound pressure without significantly increasing the complexity of the analysis. Thus, it is suitable for use with Fuller's acoustic/structural interaction model in future aircraft interior noise studies.

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References

1. Johnston, J. F., R. E. Donham, and W. A. Guinn, "Propeller Signatures and Their Use," AIAA Paper 80-1035, 1980.

2. Magliozzi, B., "Synchrophasing for Cabin Noise Reduction of Propeller-Driven Aircraft," AIAA Paper 83-0717, 1983.

3. Zalas, J. M., and J. Tichy, Active Attenuation of Propeller Blade Passage Noise, NASA CR-172386, 1984.

4. Fuller, C. R., "Noise Control Characteristics of Synchrophasing--An Analytical Investigation," AIAA Paper 84-2369, 1984.

5. Jones, J. D., and C. R. Fuller, "Noise Control Characteristics of Synchrophasing--An Experimental Investigation," AIAA Paper 84-2370, 1984.

6. Piersol, A. G., E. G. Wilby, and J. F. Wilby, Evaluation of Aero Commander Propeller Acoustic Data: Static Operations, NASA CR-158919, May 1978.

Table I. Ratio Of Theoretical To Experimental Circumferential Trace Velocities.

microphone pair	θ (rad)	v_t^{th} (m/s)	v_t^{exp} (m/s)	v_t^{th}/v_t^{exp}
3-5	0.016	69	176	0.39
4-5	0.187	118	171	0.69
3-4	0.203	125	180	0.70
4-6	0.344	223	207	1.07
5-6	0.531	538	244	2.20

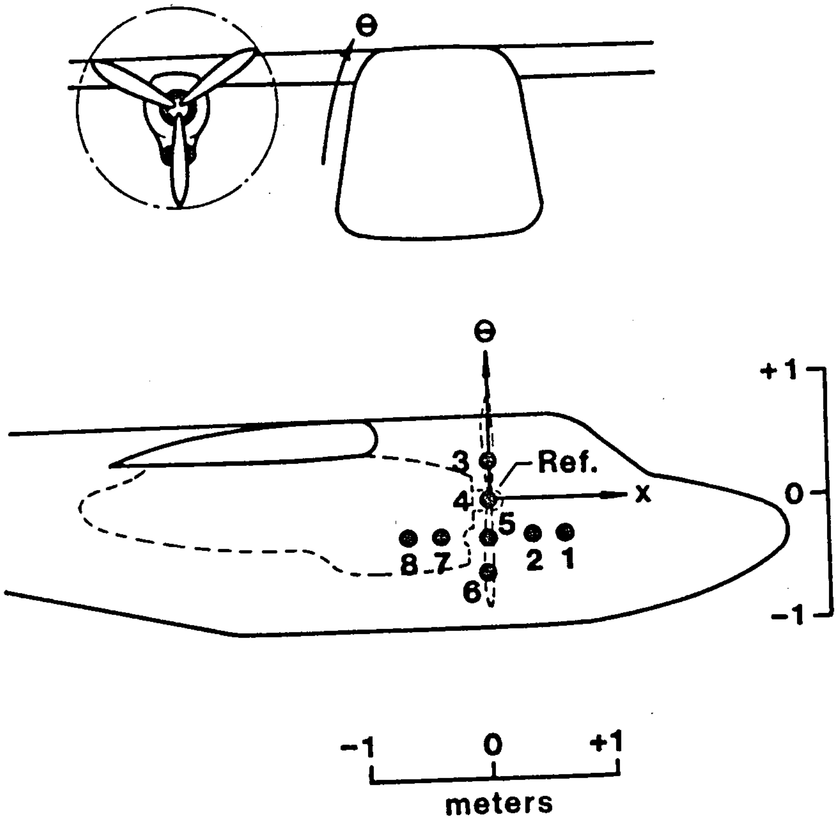


Fig. 1. Microphone Locations Corresponding To Fuselage Sound Pressure Distributions Obtained From Ref. 6.

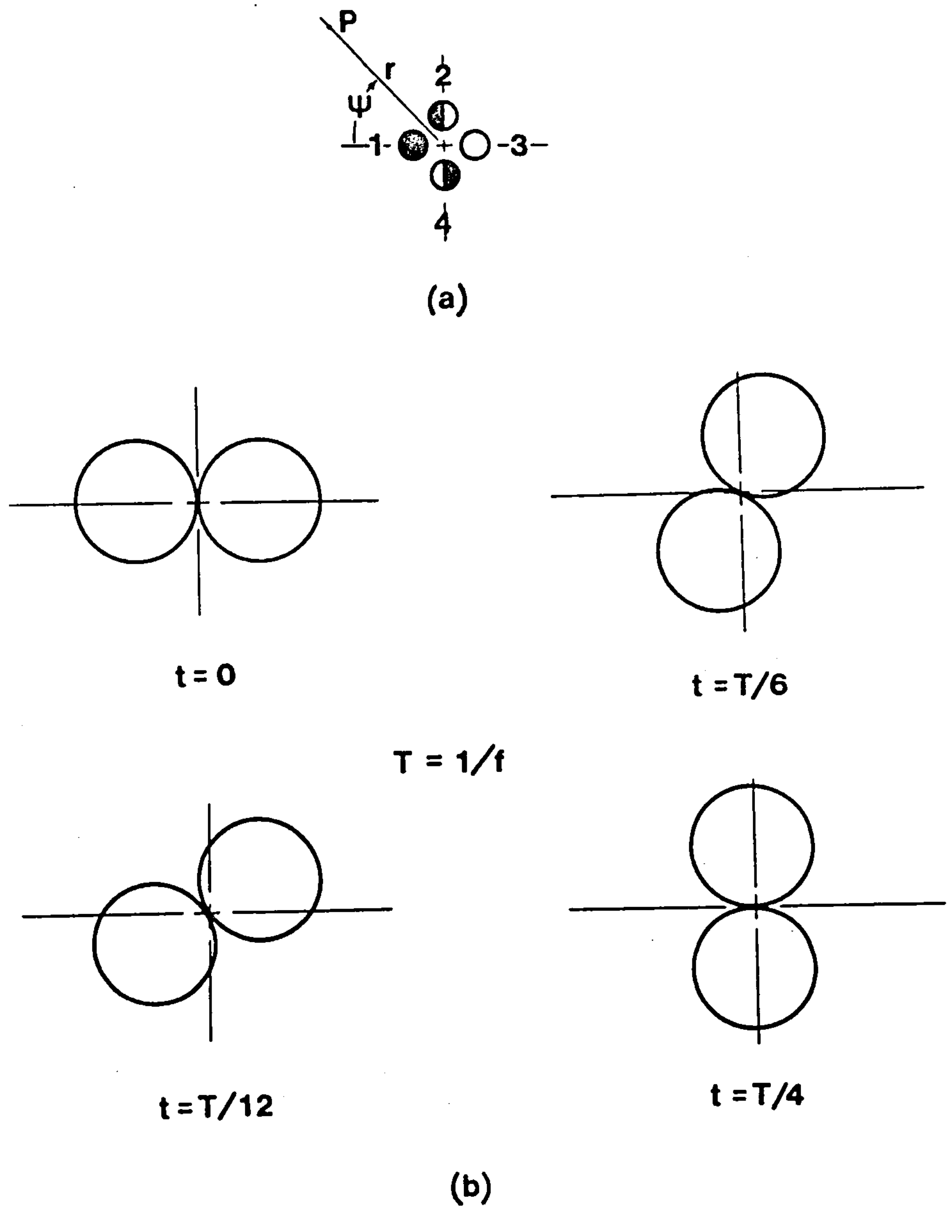


Fig. 2. (a) The Virtually Rotating Dipole Source Model and (b) Its Directivity Pattern At Four Instants In Time.

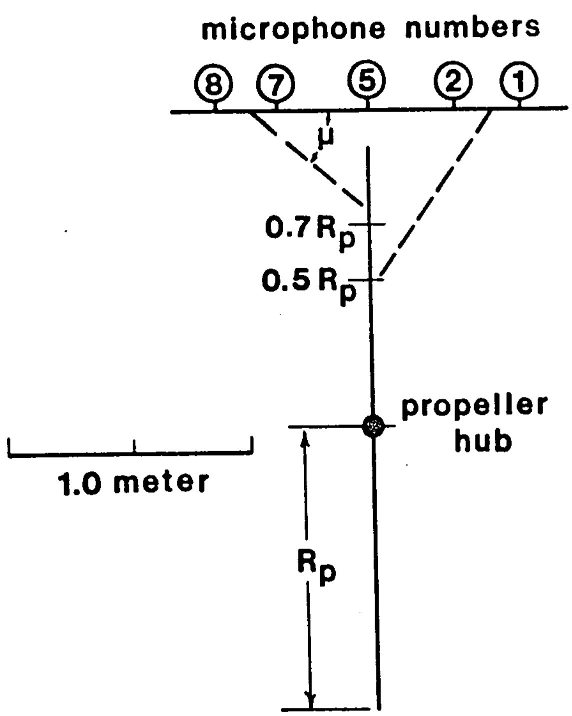
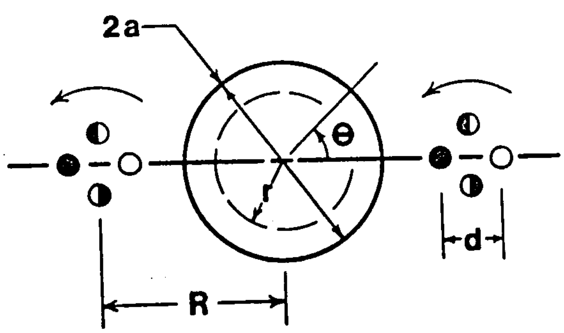


Fig. 3. Effective Source Location Based On Trace Velocity Analysis (From Ref. 6).



Sources in x/a = 0 plane.

Fig. 4. Geometric Relationship Between Compact Source Model and Cylindrical Shell Representing The Aircraft Fuselage.

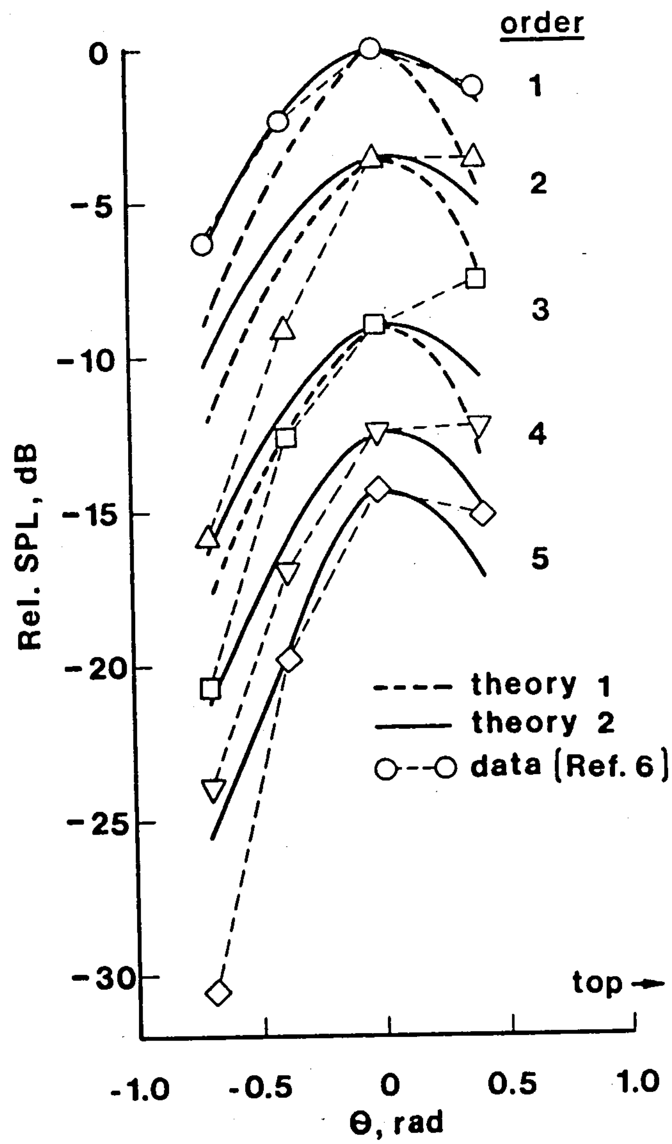


Fig. 5. Comparison Of Measured And Calculated Circumferential Sound Pressure Distributions (Theory 1 = Simple Dipole Source, Theory 2 = Virtually Rotating Dipole).

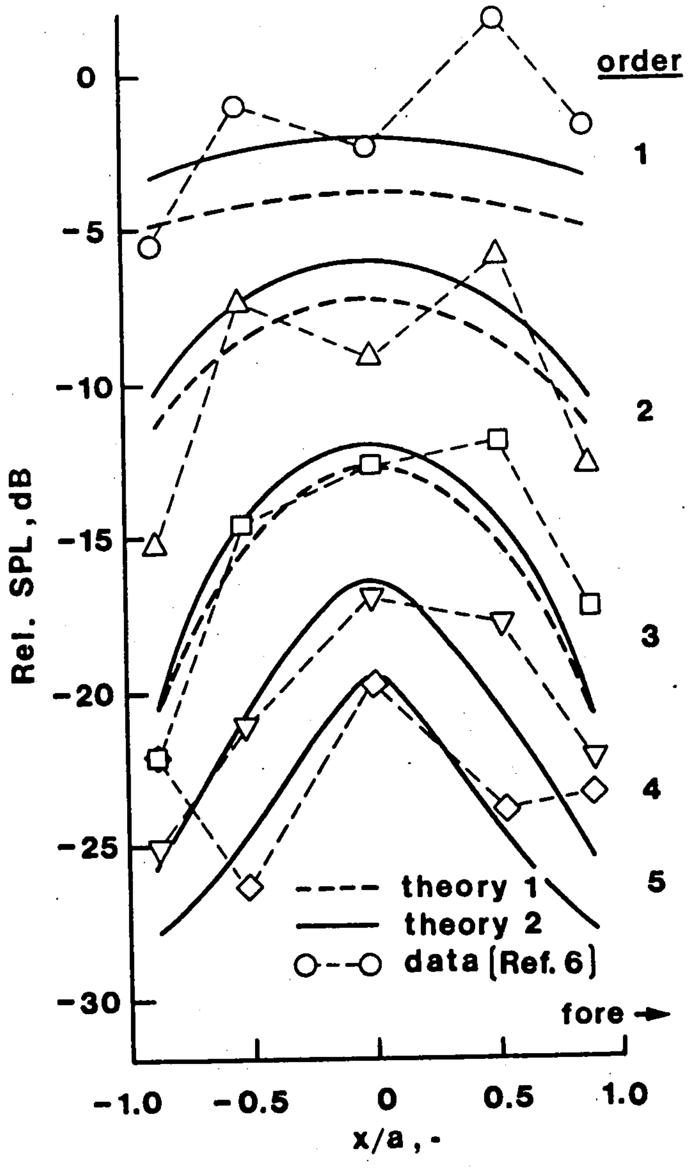


Fig. 6. Comparison Of Measured And Calculated Axial Sound Pressure Distributions (Theory 1 = Simple Dipole Source, Theory 2 = Virtually Rotating Dipole).

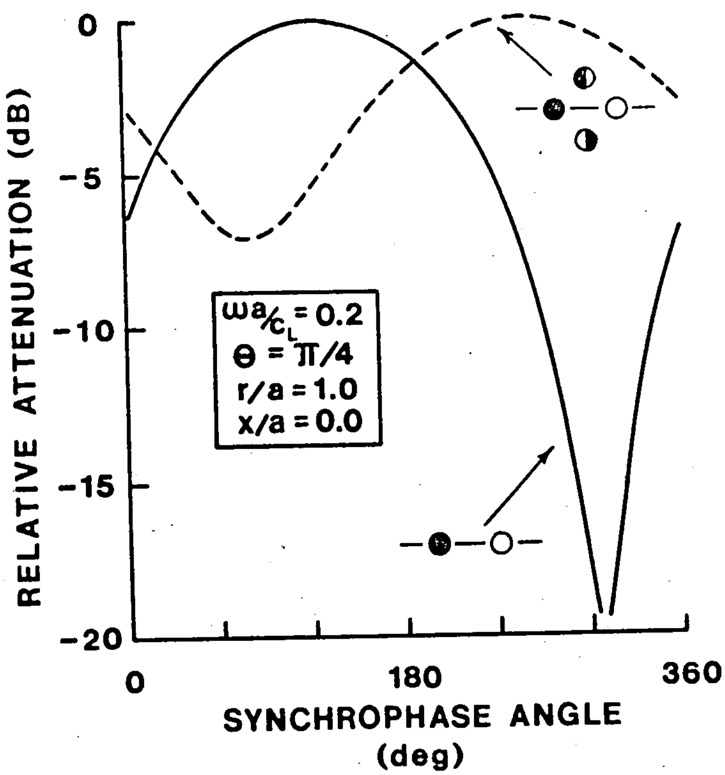


Fig. 7. Comparison Of Interior Noise Reduction Predicted By Simple Dipole And Virtually Rotating Dipole Sources ($r/a = 1.0$, $x/a = 0.0$, $\theta = \pi/4$).

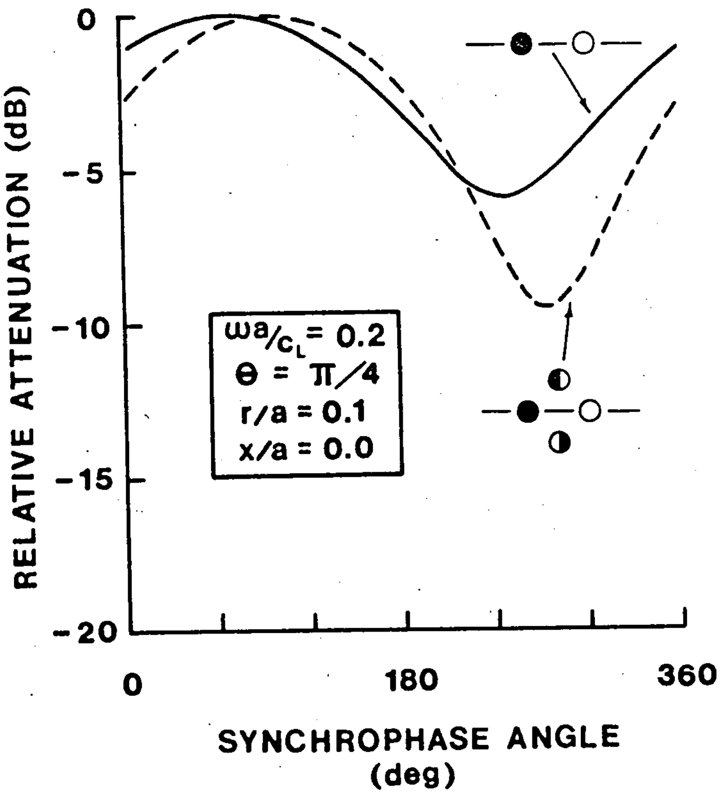


Fig. 8. Comparison Of Interior Noise Reduction Predicted By Simple Dipole And Virtually Rotating Dipole Sources ($r/a = 0.1$, $x/a = 0.0$, $\theta = \pi/4$).

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15. Supplementary Notes

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16. Abstract

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