



The prediction of shock noise from supersonic jets including the near-field

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THE PREPARATION OF THIS DATA ITEM

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THE PREDICTION OF SHOCK NOISE FROM SUPERSONIC JETS INCLUDING THE NEAR-FIELD

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THE PREDICTION OF SHOCK NOISE FROM SUPERSONIC JETS INCLUDING THE NEAR-FIELD

1. NOTATION

		<i>Si Units</i>	<i>British Units</i>
a_j	speed of sound in jet	m/s	ft/s
a_0	ambient speed of sound	m/s	ft/s
b	constant for proportional bandwidth (= 0.2316 for one-third octave bands)		
$C_1(\sigma)$	correlation coefficient spectrum		
D_j	jet nozzle diameter	m	ft
f	one-third octave band centre-frequency	Hz	Hz
$H_0(\sigma)$	group source strength spectrum	dB	dB
l	average shock cell spacing	m	ft
M_j	fully expanded jet Mach number (= V_j/a_j)		
n	number of shocks, assumed here to be 8		
p_0	ambient pressure	kPa	lbf/ft ²
r	radial distance from source to receiver	m	ft
s	shock number		
T_{js}	jet static temperature	K	K
T_0	ambient temperature	K	K
X_s	location of shock sources	m	ft
y	exponent of nozzle pressure ratio parameter, β		
V_j	fully expanded jet velocity	m/s	ft/s
β	nozzle pressure ratio parameter		
σ	frequency parameter = $2\pi fl/a_0$		
θ_j	angle between line to receiver and engine exhaust axis	deg	deg

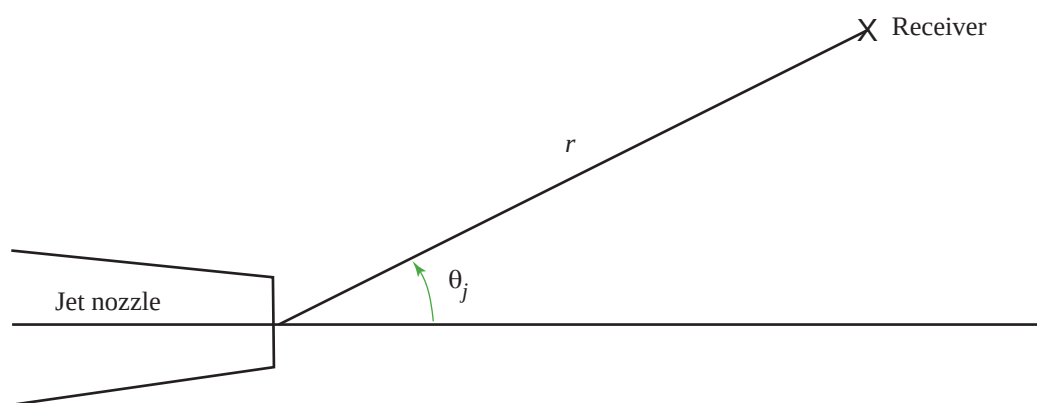
2. INTRODUCTION

The exhaust flow from a supersonic jet not fully expanded to atmospheric pressure, expands and contracts alternately until it becomes subsonic. Shocks, stationary relative to the nozzle, form in the compression regions. The interaction of the jet mixing turbulence convecting downstream through the shocks, produces shock noise, often termed shock-associated noise.

This Item allows the user to estimate shock noise levels in one-third octave bands for static nozzles. The method extends the far-field calculation method described in Derivations 1 and 2 to the near-field by repeated application of the far-field procedure, placing assumed shock cell sources at locations on the jet axis (Derivations 3 and 4). The process is described in Section 3.2.

3. THEORETICAL BACKGROUND

3.1 Far-field Prediction



Sketch 3.1

The one-third octave sound pressure level at a location in the far-field is given by

$$\begin{aligned}
 SPL(r, \theta_j) = & 10 \log_{10} 1 + \left[\frac{4}{nb} \sum_{i=1}^{n-1} \left\{ [C_1(\sigma)]^{i^2} \sum_{s=0}^{n-(i+1)} \frac{1}{\sigma q_{is}} \right. \right. \\
 & \left. \left. \times \cos(\sigma q_{is}) \times \sin\left(\frac{b\sigma q_{is}}{2}\right) \right\} \right] \\
 & + 10 \log_{10} \left[(D_j/r)^2 \beta^y \right] + 10(\log_{10}(b\sigma) + H_0(\sigma) + 148.8) \text{ dB}
 \end{aligned} \tag{3.1}$$

where

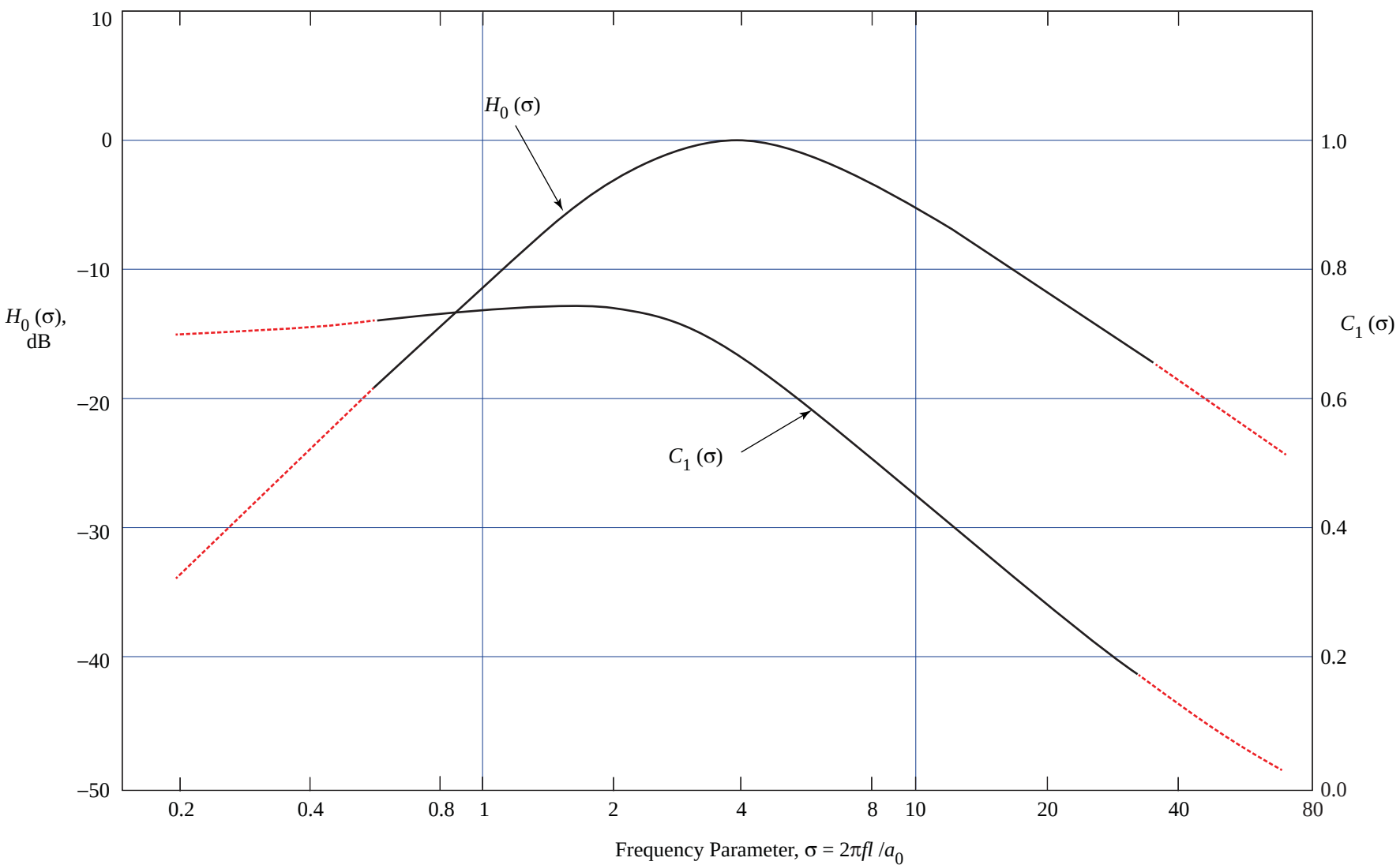
$$q_{is} = \left[1.7i/(V_j/a_0) \right] \left(1 - 0.06 \{ s + (i+1)/2 \} \right) \left(1 - 0.7(V_j/a_0) \cos \theta_j \right)$$

σ	=	dimensionless frequency parameter $2\pi fl/a_0$,
l	=	$1.1 \beta D_j$,
β	=	nozzle pressure ratio parameter $= \sqrt{M_j^2 - 1}$,
M_j	=	fully-expanded jet Mach number $= V_j/a_j$,
n	=	number of shocks, assumed to be 8,
s	=	shock number,
y	=	exponent of nozzle pressure ratio parameter, β ,
b	=	0.2316 reflecting one-third octave band proportional bandwidth,
$C_1(\sigma)$	=	correlation coefficient spectrum shown in Sketch 3.2 and in Table 3.1
and		
$H_0(\sigma)$	=	group source strength spectrum shown in Sketch 3.2 and tabulated in Table 3.1.

TABLE 3.1

σ	$H_0(\sigma)$, dB	$C_1(\sigma)$
0.2	-33.2	0.70
0.3	-27.6	0.71
0.4	-23.7	0.71
0.7	-16.1	0.72
1.0	-11.5	0.73
1.5	-6.5	0.74
2.0	-3.5	0.74
3.0	-0.7	0.71
3.5	-0.1	0.69
4.0	0.0	0.67
4.5	-0.1	0.64
5.0	-0.4	0.62
6.0	-1.3	0.58
7.0	-2.5	0.54
8.0	-3.5	0.50
10.0	-5.5	0.45
20.0	-11.8	0.28
40.0	-18.7	0.12
68.0	-23.8	0.02
70.0	-24.0	0.02

For unheated jets, the $H_0(\sigma)$ spectrum is reduced by 2 dB at all values of σ .



Sketch 3.2

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The exponent y of the nozzle pressure ratio parameter is determined as follows.

For $\beta \leq 1.0$, $y = 4$.

For $\beta > 1.0$, $y = 2$ for hot jets.

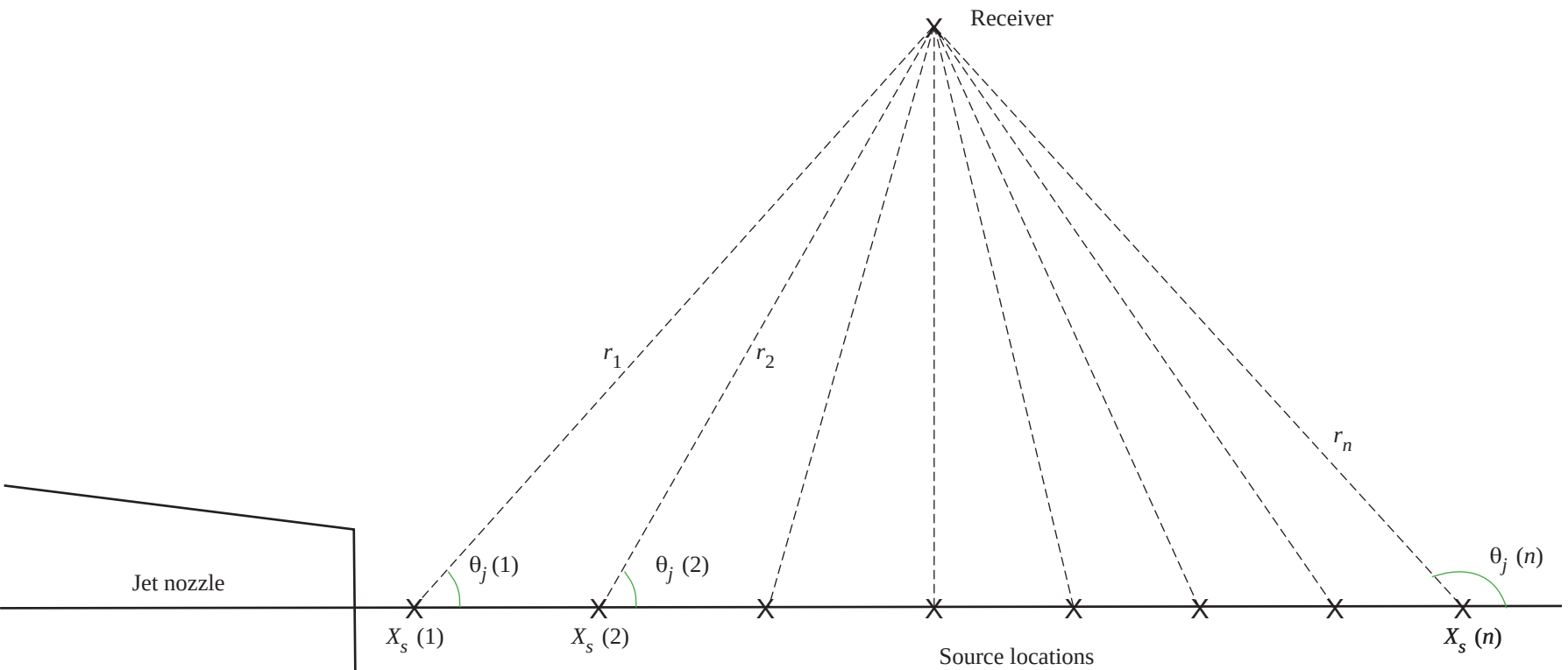
For $\beta > 1.0$, $y = 1$ for near-isothermal jets.

A heated jet is defined here in accordance with Derivation 2 as a jet where the total temperature to ambient temperature ratio is greater than 1.1.

3.2 Near-field Extension

In the region close to the jet exhaust, the near-field, the assumption of a single point noise source breaks down and a different approach is required.

The shock noise prediction is performed by summing up weighted spectra obtained by repeatedly using the far-field shock noise prediction procedure described above but with the source located at a number of shock cell locations (Sketch 3.3) rather than at the centre of the jet nozzle exit as in the far-field case (Sketch 3.1).



Sketch 3.3