

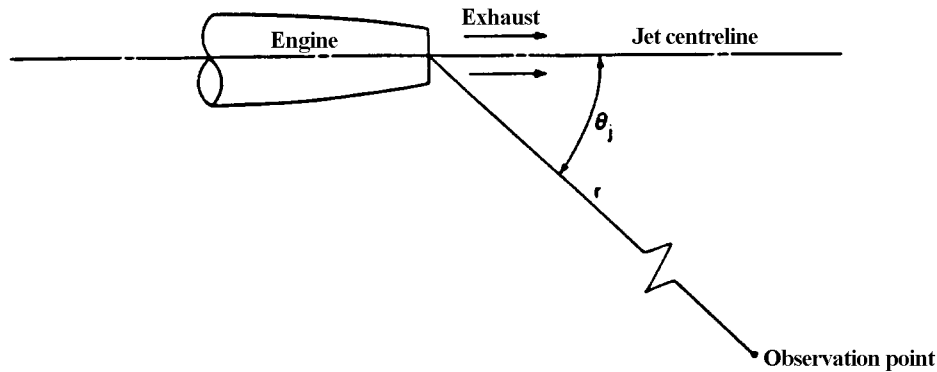
ESTIMATION OF SUBSONIC FAR-FIELD JET-MIXING NOISE FROM SINGLE-STREAM CIRCULAR NOZZLES

1. NOTATION

		Units	
		SI	British
A_j	exit area of jet exhaust nozzle	m ²	ft ²
a_0	ambient speed of sound	m/s	ft/s
d	jet exhaust nozzle diameter	m	ft
f	one-third octave band centre frequency	Hz	Hz
L	normalised overall sound pressure level	dB*	dB*
$L(f)$	one-third octave band sound pressure level	dB*	dB*
L_p	overall sound pressure level	dB*	dB*
p_{ISA}	ambient pressure under ISA conditions	N/m ²	lbf/ft ²
p_0	ambient pressure	N/m ²	lbf/ft ²
r	radial distance from nozzle exit to observer	m	ft
Sr	Strouhal number ($Sr = fd/V_j$)		
T_{js}	jet static temperature	K	K
T_0	ambient temperature	K	K
V_j	fully expanded jet velocity	m/s	ft/s
θ_j	angle between line to observer and jet exhaust axis (See Sketch 1.1)	degrees	degrees
ρ_0	density	kg/m ³	lb/ft ³
ρ_j	fully expanded jet density	kg/m ³	lb/ft ³
ω	variable density index		

* The reference pressure for all decibel levels is 20 μ Pa (i.e. 2×10^{-5} N/m²) or 0.42×10^{-6} lbf/ft².

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Sketch 1.1 Geometrical configuration

2. NOTES

This Data Item gives a graphical method of estimating the overall sound pressure level and one-third octave band sound pressure levels of far-field, shock-free jet-mixing noise emanating from a static circular nozzle exhausting into the atmosphere. These levels may be estimated over the angular range $30^\circ \leq \theta_j \leq 120^\circ$. The frequency range is defined by the $\log_{10} Sr$ range between -1.5 and approximately 1.1 . The range of jet operating conditions over which the method may be used is indicated by the unshaded region in the following Sketch.

		V_j/a_0				
		0.5	0.75	1.0	1.25	1.5
T_{js}/T_0	2.5					
	2.0					
	1.5					
	1.0					

Sketch 2.1

Within the ranges described above the r.m.s. error between calculated and measured one-third octave band sound pressure levels is of the order of 0.5 dB. The procedure of calculation is similar to that described in Derivation 3, but the database used has been obtained from static tests described in Derivation 2.

This Data Item is based on experimental data from model jets in which sources of noise other than pure jet-mixing noise have been eliminated. Effects of atmospheric absorption and ground reflection are not included.

A simple introduction to jet mixing noise, together with other types of gas turbine exhaust noise is given in Item No. 74001 (Reference 4). A computerised method of estimating single-stream exhaust noise spectra is given in Item No. 85018 (Reference 5).

3. CALCULATION METHOD

3.1 Overall Sound Pressure Level

The overall sound pressure level, over the frequency range defined by $-1.5 \leq \log_{10} Sr \leq 1.1$, at position r, θ_j , may be calculated from the equation

$$L_p = L + 10 \log_{10}(\rho_j/\rho_0)^\omega + 10 \log_{10}(A_j/r^2) + 20 \log_{10}(p_0/p_{ISA}), \quad (3.1)$$

which for the fully expanded jet condition may be written as

$$L_p = L + 10 \log_{10}(T_0/T_{js})^\omega + 10 \log_{10}(A_j/r^2) + 20 \log_{10}(p_0/p_{ISA}), \quad (3.2)$$

where L is obtained from Figure 1 for particular values of $\log_{10}(V_j/a_0)$ and θ_j ,

and ω is obtained from Figure 2* for the particular values of $\log_{10}(V_j/a_0)$.

3.2 Spectrum Pressure Levels

The one-third octave band sound pressure level, $L(f)$ centred at frequency f , at position r, θ_j , may be calculated for a given set of jet operating conditions from Figures 3 – 12. Data from these figures are presented in tabular form in Appendix A. For each angle θ_j , the term $[L(f) - L_p]$ is plotted as a function of $\log_{10} Sr$ for different combinations of T_{js}/T_0 and V_j/a_0 . Once this term has been read off the appropriate figure, $L(f)$ may simply be obtained by adding the term to L_p obtained as described in Section 3.1.

4. DERIVATION AND REFERENCES

4.1 Derivation

This Section lists selected sources that have assisted in the preparation of this Item.

- | | | |
|----|---|---|
| 1. | HOCH, R.G.
DUPONCHEL, J.P.
COCKING, B.J.
BRYCE, W.D. | Studies of the influence of density on jet noise. First International Symposium on Air Breathing Engines, Marseille, 1972. (Also published in <i>J. Sound. Vib.</i> , Vol. 28, No. 4, pp.649- 668, 1973.) |
| 2. | BRYCE, W.D. | The prediction of static-to-flight changes in jet noise. AIAA – 84-2358, AIAA/NASA 9th Aeroacoustics Conference, October 1984. |
| 3. | S.A.E. | Gas turbine jet exhaust noise prediction. ARP 876C, Society of Automotive Engineers, Inc., Warrendale, Pa, USA, November 1985. |

* Figure 2 has been obtained from Derivation 1 and includes modification at higher values of $\log_{10}(V_j/a_0)$ from Derivation 3.

4.2 References

The following sources provide information supplementary to that given in this Item.

4. ESDU An introduction to gas turbine exhaust noise. Item No. 74001, ESDU International plc, London, UK, June 1973.
5. ESDU Computer-based estimation procedure for single-stream jet noise. Including far-field, static-jet mixing noise database for circular nozzles. Item No. 85018, ESDU International plc, London, UK, August 1985.

5. EXAMPLE

Estimate the far-field overall sound pressure level of jet-mixing noise, at sea level, emanating from a circular nozzle at a radial distance of 75 m and $\theta_j = 60$ degrees. Estimate also the one-third octave band sound pressure levels in the bands centred at 125 Hz and 500 Hz. The static single-stream jet source has a circular nozzle of 0.3 m diameter and is operated at $V_j = 251.2$ m/s and $T_{js} = 418.5$ K. The ambient temperature T_0 is 279 K and the ambient pressure is 101325 Pa.

(a) Overall Sound Pressure Level

The ambient speed of sound, a_0 , is given by

$$\begin{aligned} a_0 &= 20.05 \sqrt{T_0} \text{ m/s} \\ &= 20.05 \sqrt{279.0} = 334.9 \text{ m/s.} \end{aligned}$$

$$\text{Therefore, } \log_{10} \left(\frac{V_j}{a_0} \right) = \log_{10} \left(\frac{251.2}{334.9} \right) = -0.125.$$

$$\text{From Figure 1, for } \log_{10} \left(\frac{V_j}{a_0} \right) = -0.125 \text{ and } \theta_j = 60^\circ, L = 133.0 \text{ dB.}$$

$$\text{From Figure 2, for } \log_{10} \left(\frac{V_j}{a_0} \right) = -0.125, \omega = 0.1.$$

At sea level, the ambient pressure under ISA conditions, p_{ISA} , is 101325 Pa.

$$\text{Therefore, } \frac{p_0}{p_{ISA}} = 1.0.$$

$$\text{Now } \left(\frac{T_0}{T_{js}} \right)^\omega = \left(\frac{279}{418.5} \right)^{0.1} = 0.960,$$

$$\text{and } \frac{A_j}{r^2} = \frac{\pi \times 0.3^2}{4 \times 75^2} = 1.26 \times 10^{-5}.$$

From Equation (3.2)

$$\begin{aligned} L_p &= L + 10 \log_{10}(T_0/T_{js})^\omega + 10 \log_{10}(A_j/r^2) + 20 \log_{10}(p_0/p_{ISA}) \\ &= 133.0 - 0.18 - 49.01 + 0.0 \\ &= 83.8 \text{ dB}. \end{aligned}$$

(b) One-third Octave Band Levels

(i) For the one-third octave band centred at 125 Hz,

$$\begin{aligned} \log_{10} Sr &= \log_{10} \left(\frac{fd}{V_j} \right), \\ &= \log_{10} \left(\frac{125 \times 0.3}{251.2} \right) = -0.826. \end{aligned}$$

$$\text{Now } \frac{T_{js}}{T_0} = \frac{418.5}{279} = 1.5,$$

$$\frac{V_j}{a_0} = \frac{251.2}{334.9} = 0.75,$$

and, from Figure 6,

$$L(f) - L_p = -15.2 \text{ dB}.$$

$$\text{Therefore } L(f) = L_p - 15.2,$$

$$= 83.8 - 15.2 = 68.6 \text{ dB}.$$

(ii) For the one-third octave band centred at 500 Hz,

$$\log_{10} Sr = \log_{10} \left(\frac{500 \times 0.3}{251.2} \right) = -0.224,$$

and, from Figure 6,

$$L(f) - L_p = -11.0 \text{ dB}.$$

$$\text{Therefore } L(f) = 83.8 - 11.0 = 72.8 \text{ dB}.$$

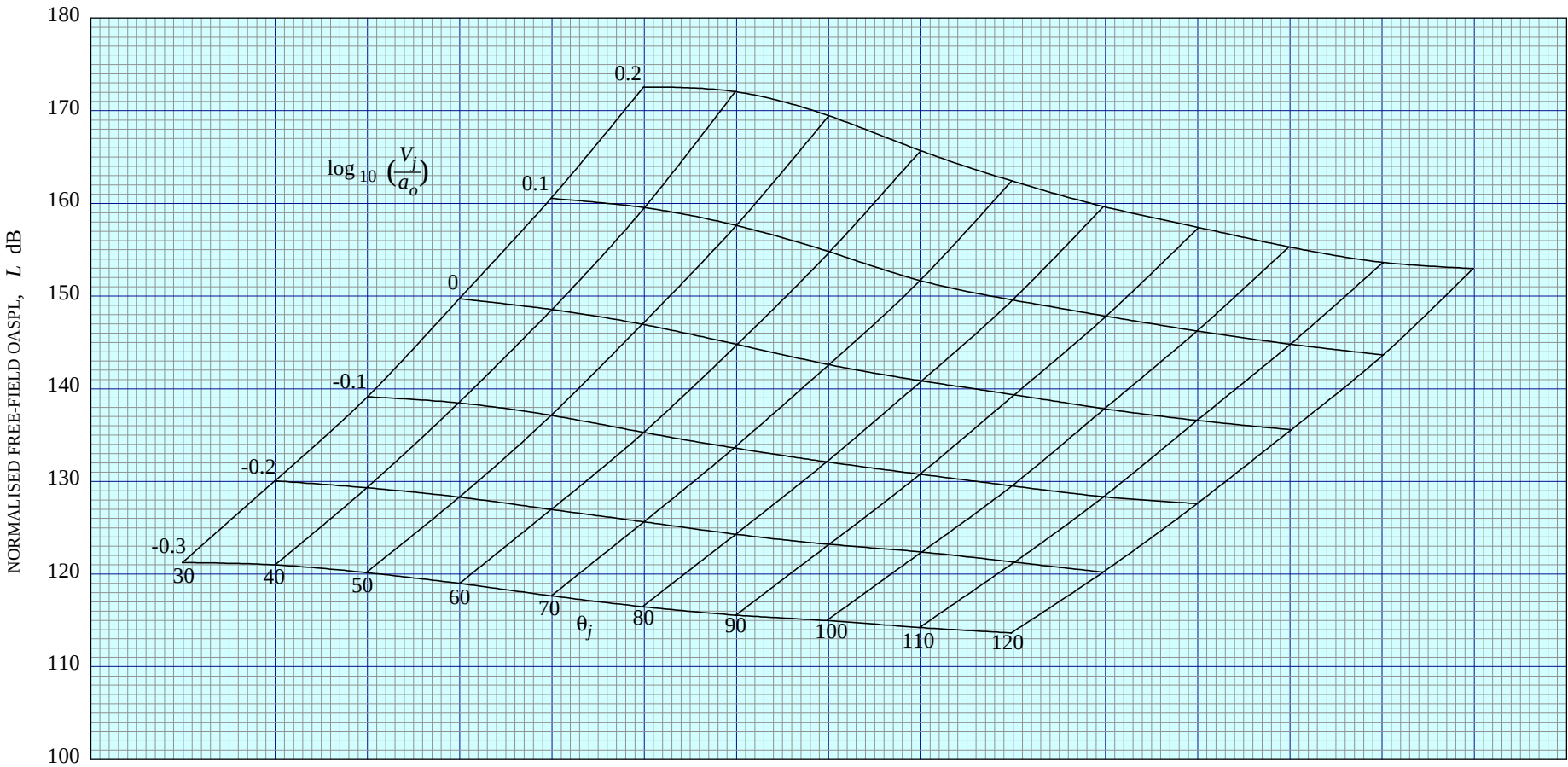


FIGURE 1 NORMALISED OVERALL SOUND PRESSURE LEVEL, L

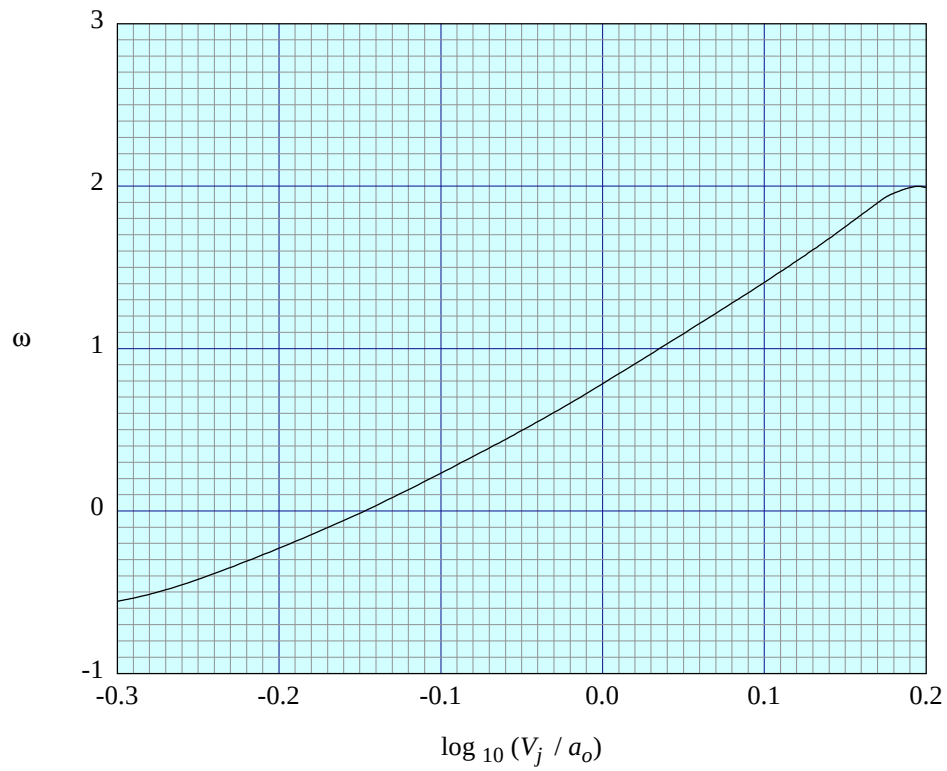


FIGURE 2 VARIABLE DENSITY INDEX, ω

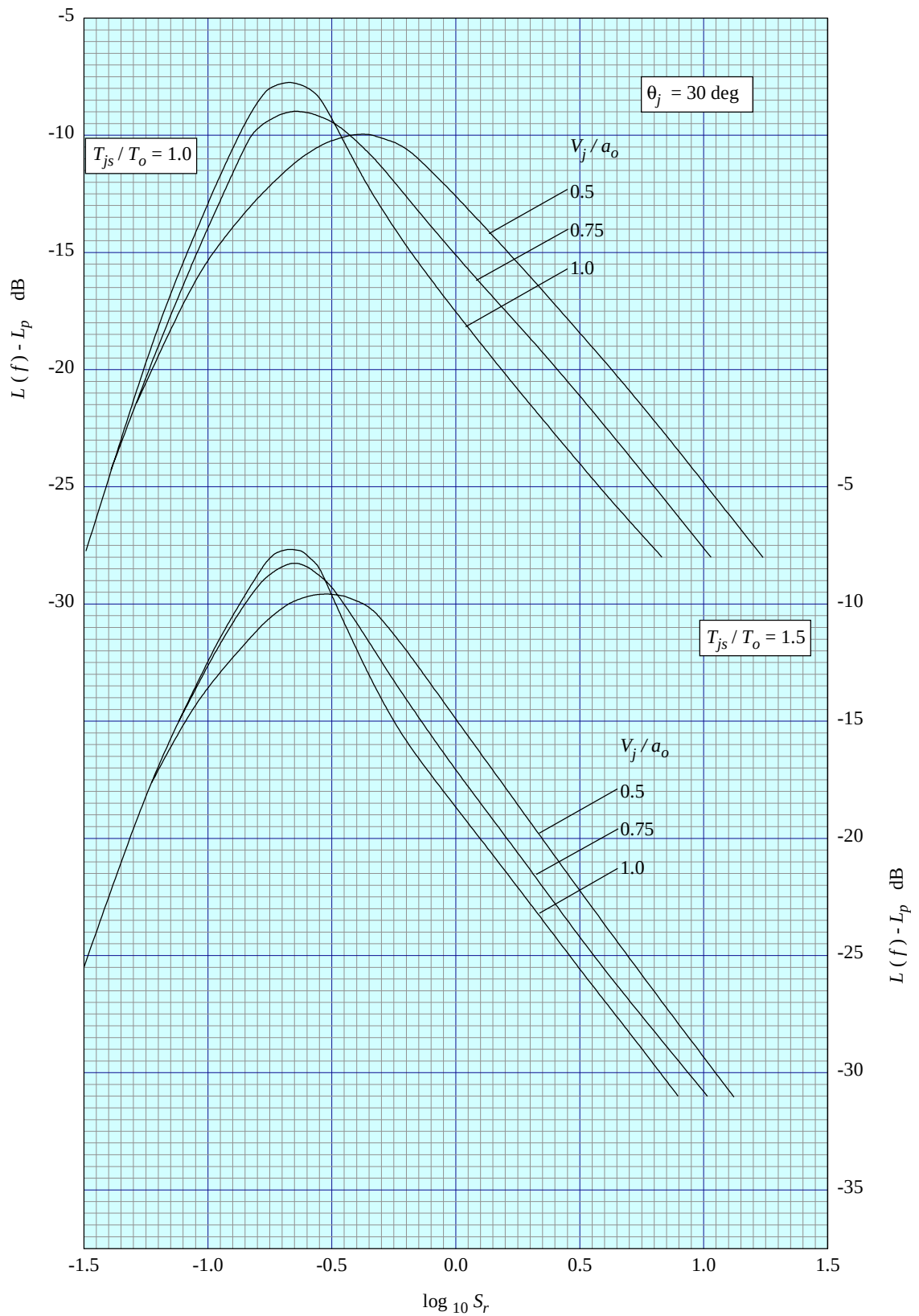


FIGURE 3a NORMALISED SPECTRA FOR $\theta_j = 30 \text{ deg}$

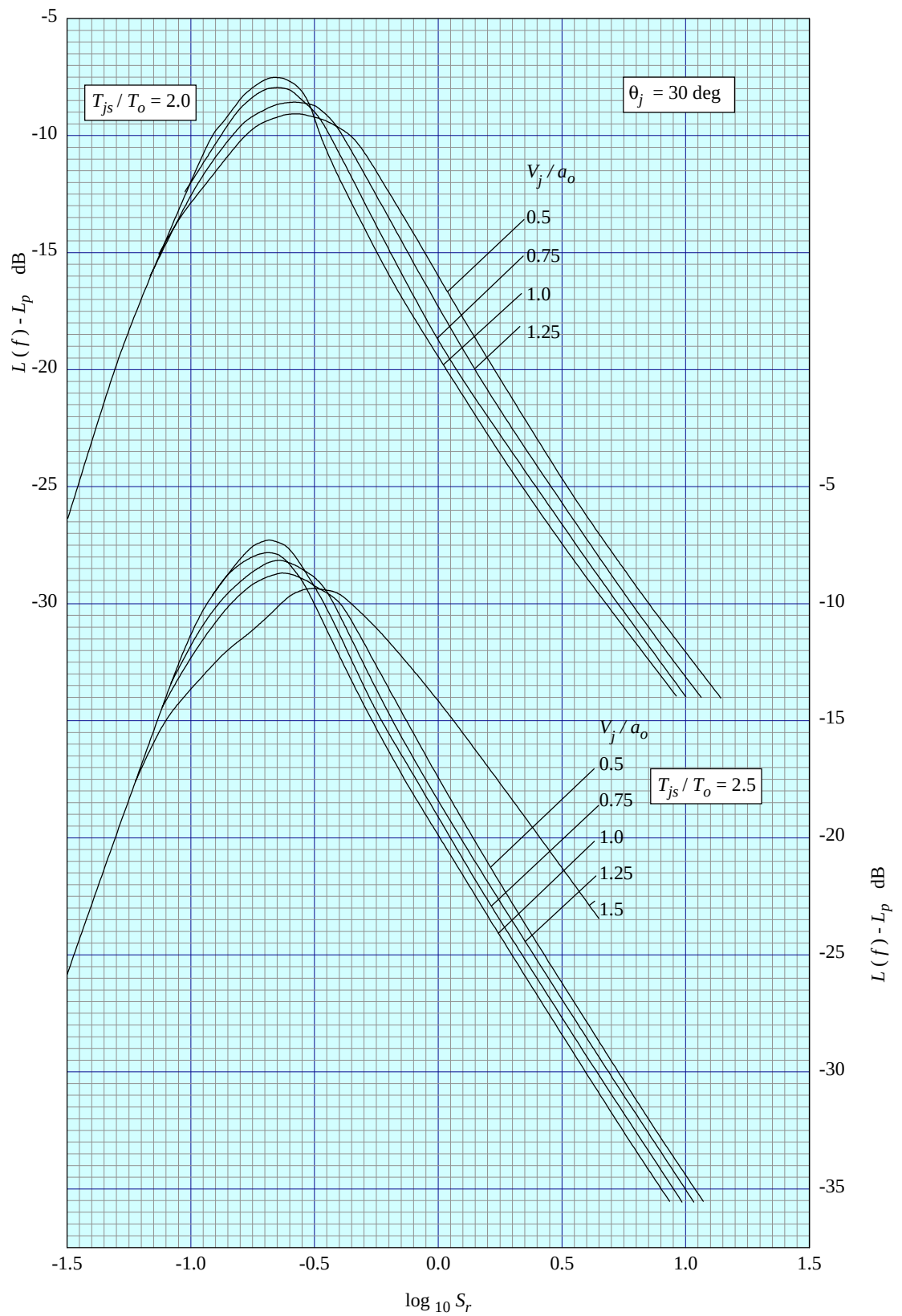


FIGURE 3b (continued) NORMALISED SPECTRA FOR $\theta_j = 30 \text{ deg}$

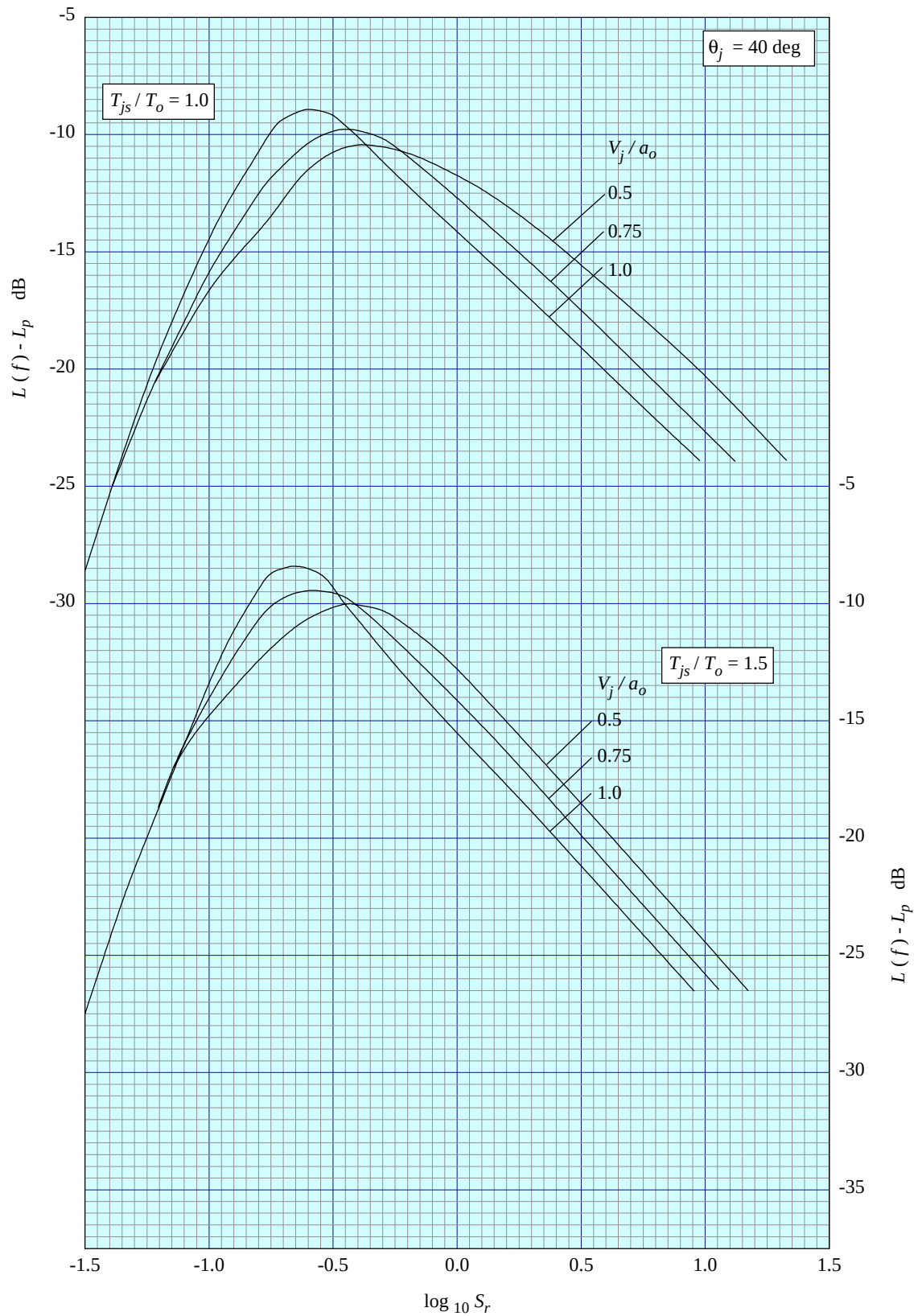


FIGURE 4a NORMALISED SPECTRA FOR $\theta_j = 40^\circ$

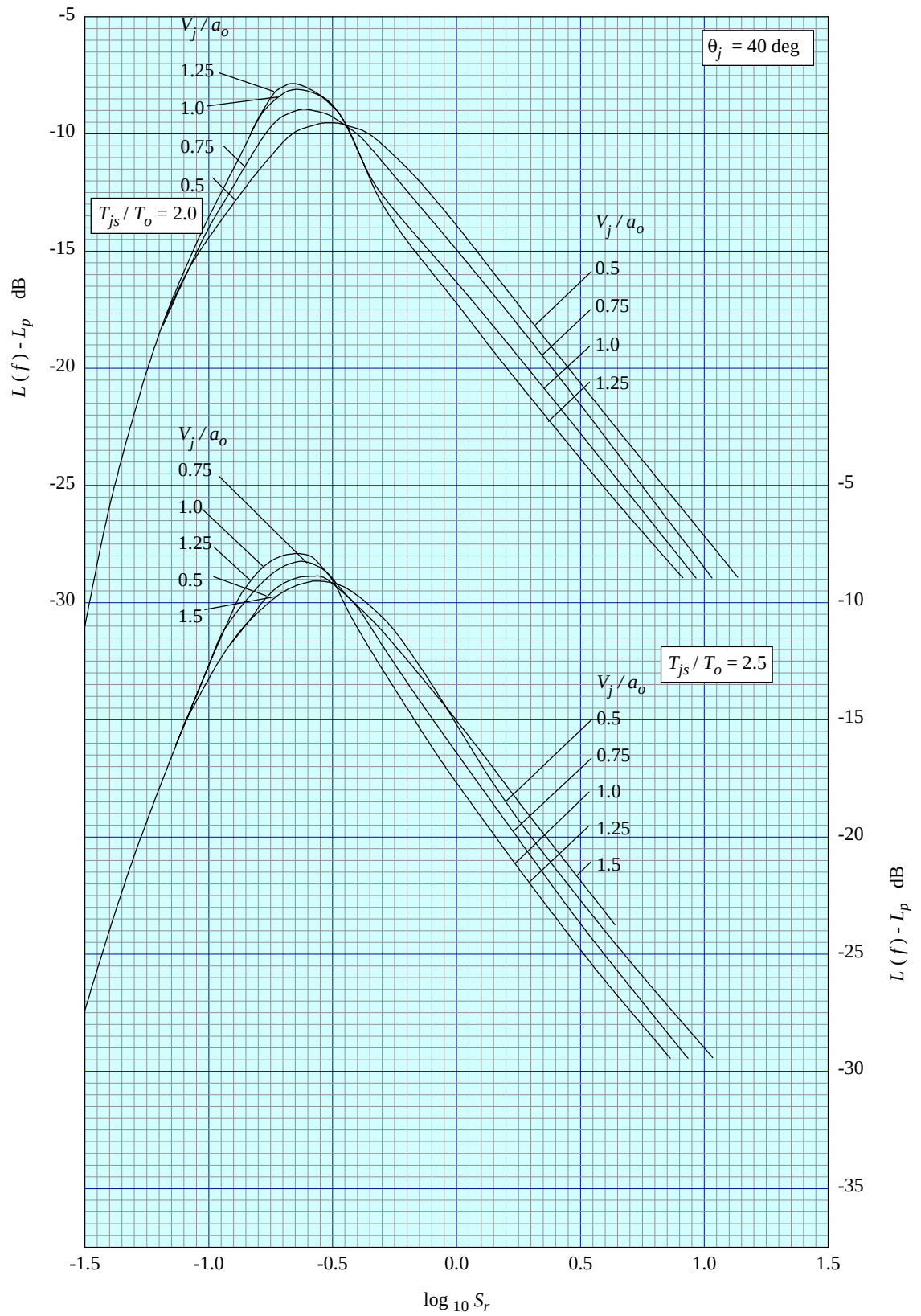


FIGURE 4b (continued) NORMALISED SPECTRA FOR $\theta_j = 40 \text{ deg}$

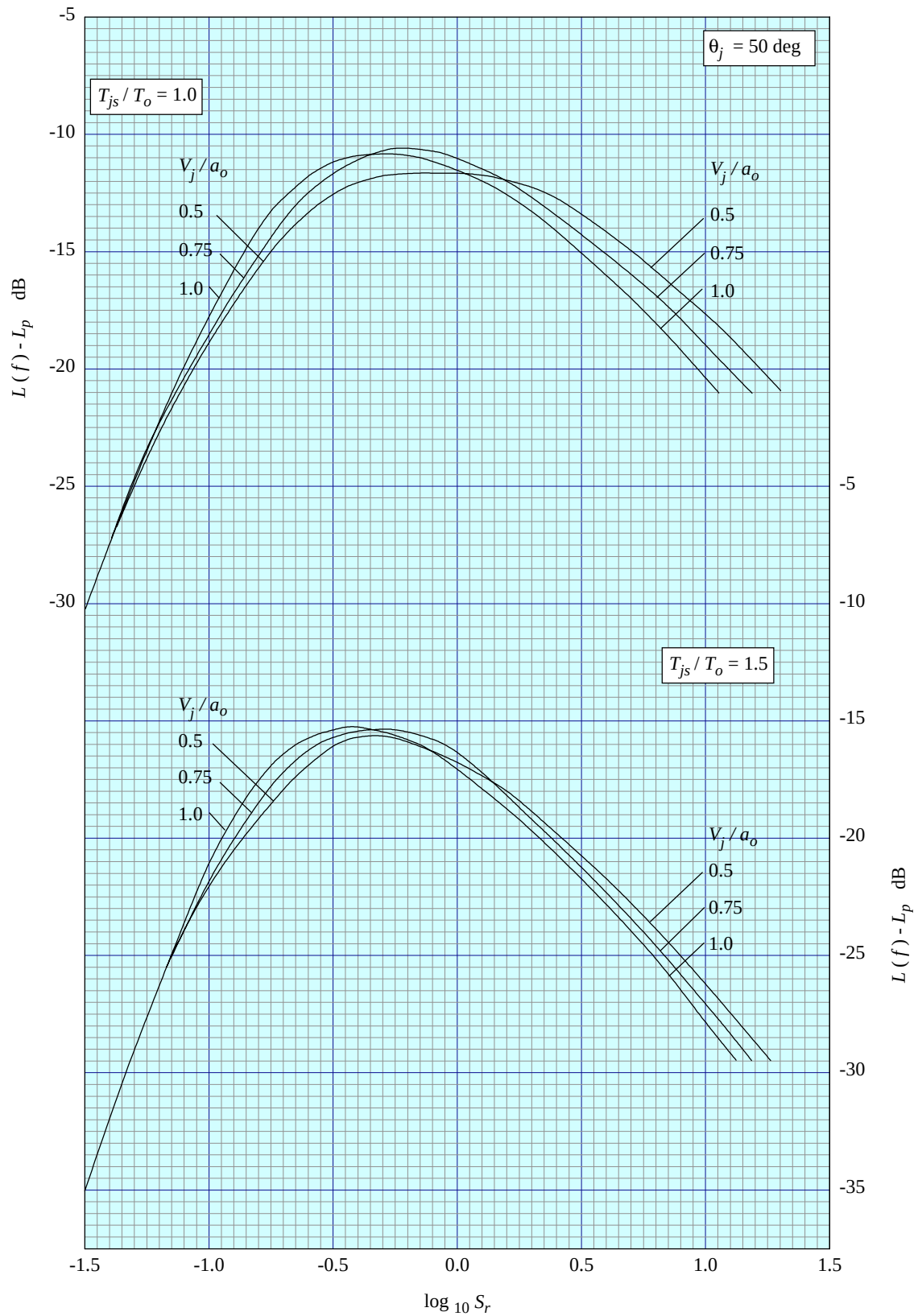


FIGURE 5a NORMALISED SPECTRA FOR $\theta = 50^\circ$

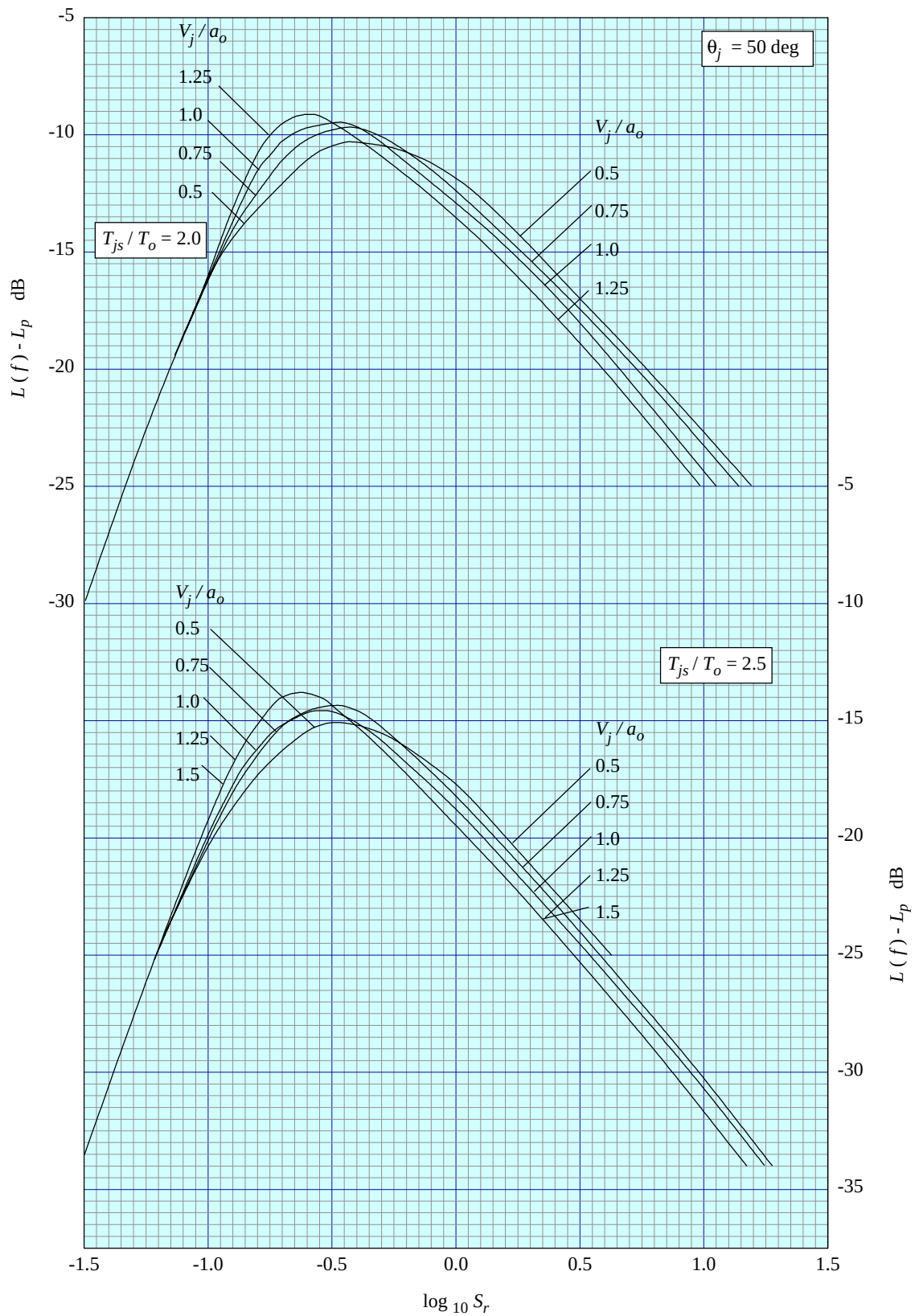


FIGURE 5b (continued) NORMALISED SPECTRA FOR $\theta_j = 50 \text{ deg}$

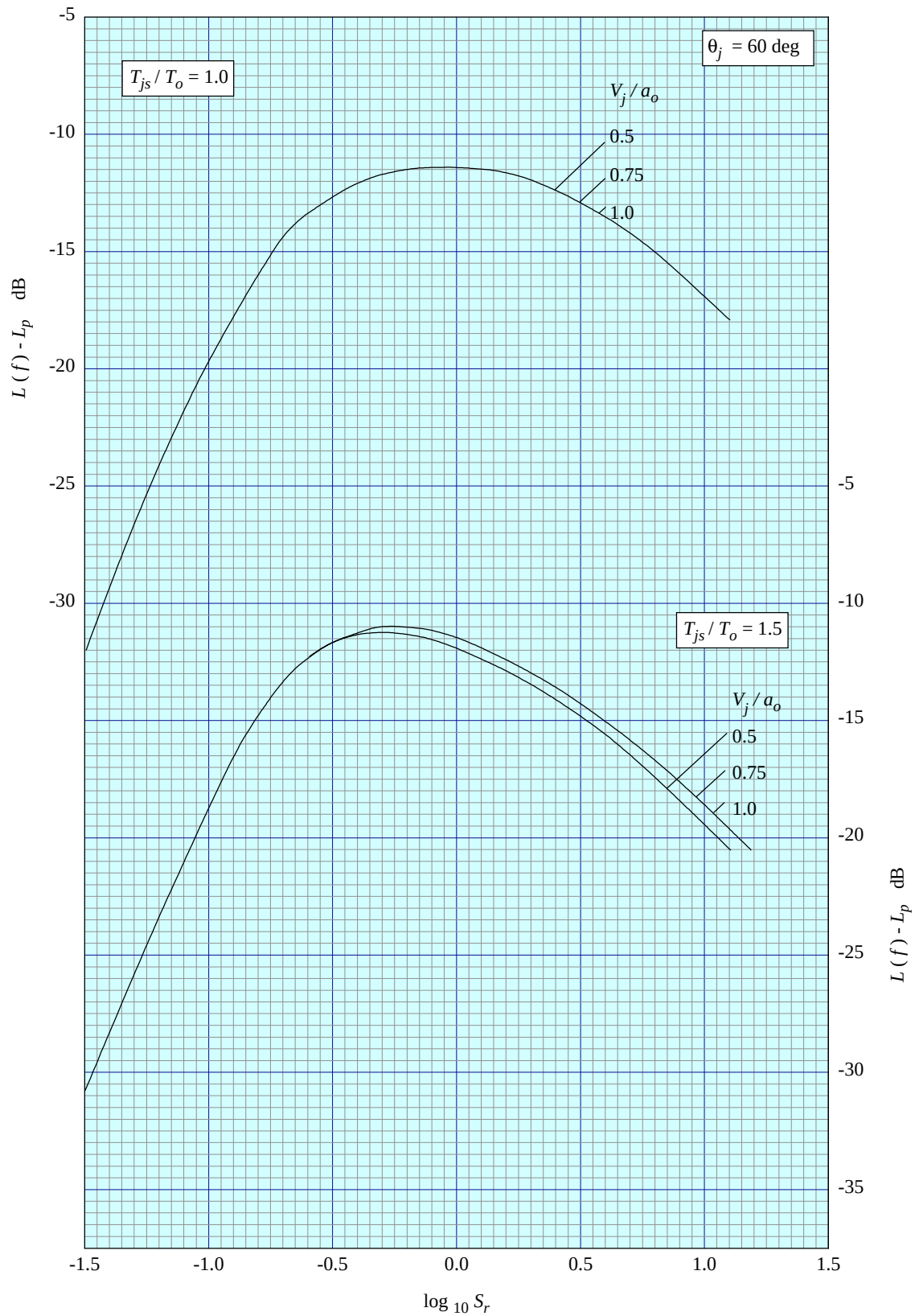


FIGURE 6a NORMALISED SPECTRA FOR $\theta_j = 60 \text{ deg}$

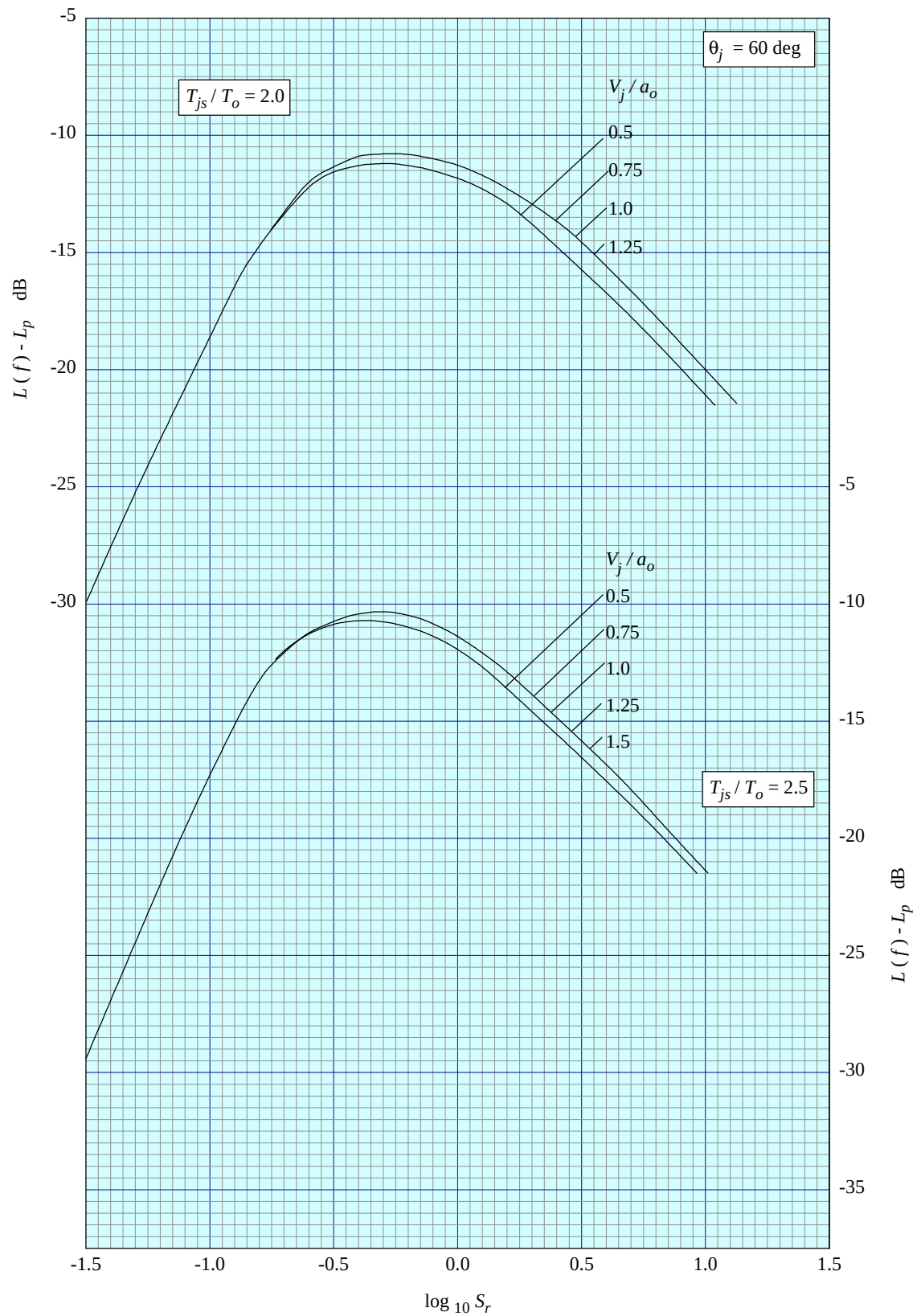


FIGURE 6b (continued) NORMALISED SPECTRA FOR $\theta_j = 60 \text{ deg}$