Chapter 15

15.1 Using the sample code given on www.aeroacoustics.net to compute trailing edge noise usimg the BPM method, investigate the relative contribution of the three separate components identified by BPM as contributing to the TBL-TE noise: the pressure side boundary layer, the suction side boundary layer, and separation of the suction side boundary layer. Use the BPM predictions to determine the displacement thicknesses for a tripped airfoil. Plot and discuss the relative (to each other) and absolute changes of each of these components with increasing angle of attack from 0° to 12°. Remember, the BPM relations were derived from an extensive evaluation of a series of NACA 0012 airfoils. How may these results change when considering airfoils with an asymmetric profile? The given Matlab function requires all inputs specified on lines 3-13. You should assume a distance from the retarded source position to observer of 5 m with the observer located directly over the trailing edge at the spanwise center location of the airfoil. Assume the airfoil is tripped and is operating in air. Other necessary parameters are detailed below. Note: These are typical values for tests conducted in the Virginia Tech Stability Wind Tunnel.

- c = 0.914m
- b = 1.8 m
- U_∞ = 60 m/s

Worked example solution

15.2 A rectangular wing of a UAV has a tripped NACA 0012 section at 0° angle of attack, with a span of 1.3-m and chordlength of 20cm. The UAV has a designed cruise speed of 68m/s.

(a) Using the code given on www.aeroacoustics.net to implement the BPM method, calculate the trailing edge noise spectrum produced by the airfoil at an observer position 5-m below the trailing edge of the wing centered spanwise at cruise. Plot your results as 1/3rd octave band SPL vs frequency in Hz from 561Hz to 7127Hz using a logarithmic scale. Only present data at the standard mid-band frequencies for 1/3rd octave bands within this frequency range.

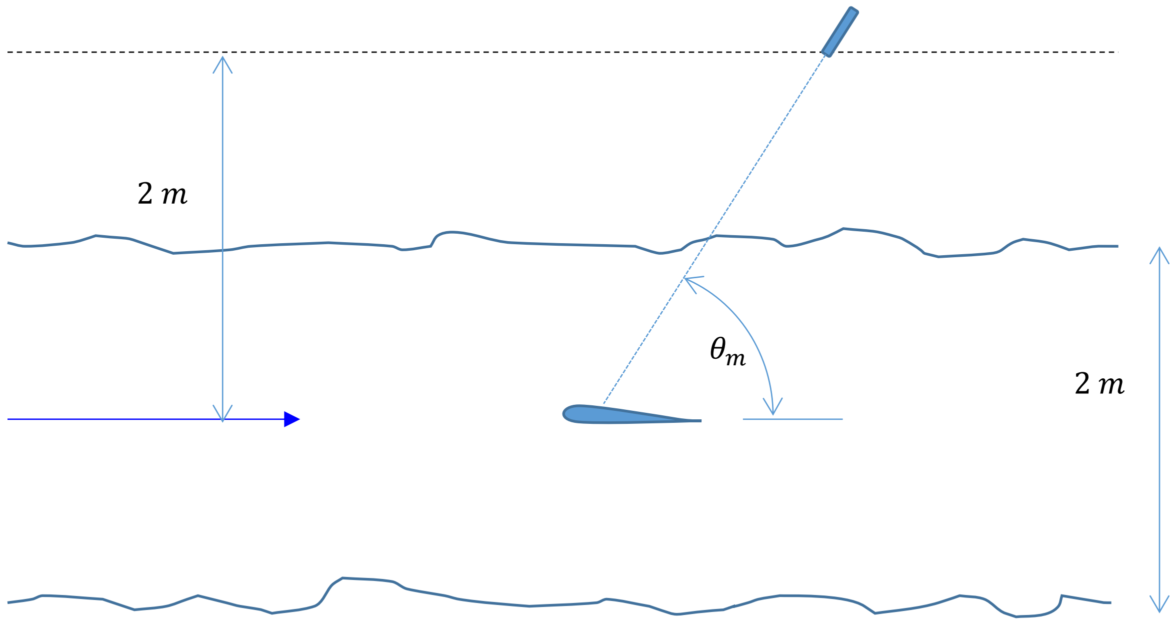
(b) Calculate, using results from Chapter 14, the leading edge noise spectrum heard by the same observer for the same conditions if the UAV is flying though turbulence with a mean square intensity $\overline{u^2}$ of 0.2 m^2/s^2 and longitudinal integral scale of 7 cm. Plot your results as a spectral density, as SPL vs frequency in Hz from 561Hz to 7127Hz using a logarithmic scale.

(c) In another test, the trailing edge noise and leading edge noise spectra were found to conform to the empirical equations below. Calculate and plot the total noise spectrum from the combined leading and trailing edge noise contributions in 1/3rd octave band SPL vs frequency.

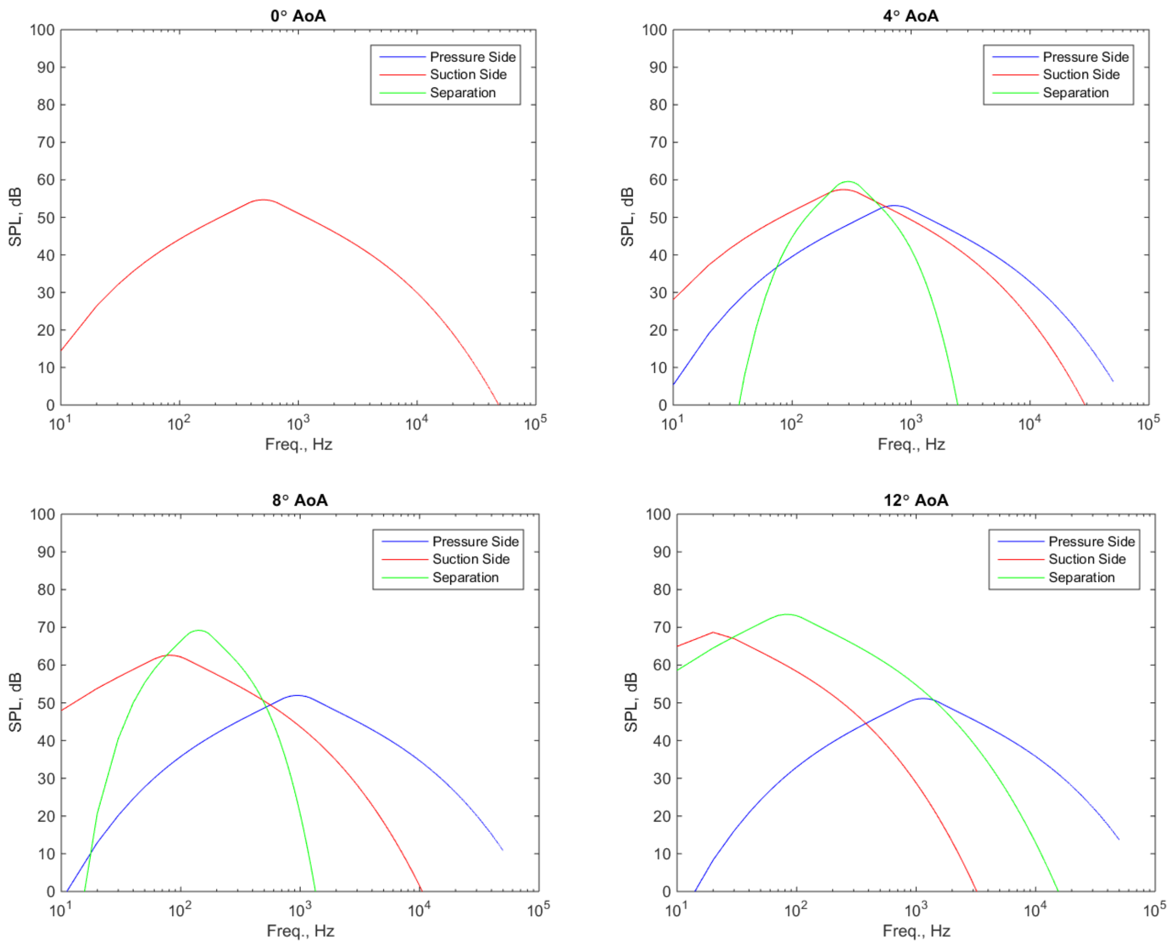
Third-Octave Band Trailing Edge Noise Spectrum: $SPL_{1/3} = 75 + 40\ln\left(\frac{f}{2000}\right) - 30\ln\left(1+\left(\frac{f}{2000}\right)^2\right)$

Narrowband Leading Edge Noise Spectrum in Spectral Density per Hz: $SPL = 37 + \log_{10}\left(\left(\frac{f}{1000}\right)^{-25}\right)$

(d) The UAV is tested by mounting it at the center of the 2m by 2m square test section of an open jet anechoic tunnel. Microphones are to be placed 2m from the center of the test section, as shown. Using charts from Chapter 10, determine the effective receiver angles θ_c of microphones placed at nominal receiver angles θ_m of 45, 90 and 135 degrees, and the correction in dB that would need to be applied to measurements made with the 135 degree mic.



Solution Problem 15.1



At zero degrees, there is negligible separation noise and the pressure and suction side contributions are the same. (This empirical relation was determined for a symmetric airfoil!) For an asymmetric profile these would not be equal at zero degree AoA. As the angle of attack increases the separation noise quickly rises and becomes a significant contributor although over a much narrower frequency range. With increasing AoA, as the suction side boundary layer thickens, the contribution from the suction side increases in magnitude and shifts to lower frequencies. The opposite is true for the pressure side although the magnitude of the frequency and amplitude changes are much smaller relative to the suction side.

```
clear all; close all;

alpha=[0:4:12];

parm.r_e = 5; % Retarded source to observer distance, in m, scalar.
parm.theta= 90; % Retarded source to observer angle in degrees measured from
downstream, scalar
parm.phi = 90; %Lateral directivity angle term in degrees, scalar
parm.c = 0.914; %Chordlength(m). Scalar or 1xN vector
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parm.L = 1.8; %Span (m). Scalar or 1xN vector
parm.U=60; %Free stream velocity. Scalar or 1xN vector
parm.v = 0.0000181206/1.22500; %Kinetmatic Viscosity of air in m^2/s
parm.c0 = 340; %Speed of sound in m/s
parm.trip=1; %Trip condition, 0 - untripped, 1 - tripped (BPM fit), 2 -
prescribed delta*
parm.plot=0;

for mm=1:length(alpha)
    parm.alpha= alpha(mm); % Retarded source to observer angle in degrees
measured from downstream, scalar

[f(mm,:),SPL_TOT(mm,:),SPL_S(mm,:),SPL_P(mm,:),SPL_A(mm,:),deltaS_p(mm),delta
S_s(mm)]=BPM_TBL_TE_Noise(parm);

    figure(mm)
    semilogx(f(mm,2:end),SPL_P(mm,2:end),'b')
    hold on
    semilogx(f(mm,2:end),SPL_S(mm,2:end),'r')
    semilogx(f(mm,2:end),SPL_A(mm,2:end),'g')
    ylim([0 100])
    xlabel('Freq., Hz')
    ylabel('SPL, dB')
    legend('Pressure Side','Suction Side','Separation')
end
```