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Introduction to Acoustics

Homework 4

I. The intensity transmission coefficient for sound at a frequency ω through a wall of thickness $L = o.1m$ separating air and water is given by

$$T_I = \frac{4}{2 + (r_3/r_1 - r_1/r_3)cos^2 k_2 L + (r_2^2/r_1 r_3 + r_1 r_3/r_2^2)sin^2 k_2 L}, \qquad (1)$$

ere $k_2 = \omega/c_2$.

1. Plot T_I versus the frequency f in Hz and particularly show what happened when $k_2 L \approx n\pi$ and $k_2 L \approx (n - \frac{1}{2})\pi$.
2. Estimate the narrow band of frequencies when $k_2 L \approx n\pi$ and $k_2 L \approx (n - \frac{1}{2})\pi$.

II. A harmonic plane wave propagating in a fluid with density ρ_1 and speed of sound c_1 encounters another fluid with density ρ_2 and speed of sound c_2. Let the x-axis be the normal to the fluid interface and the y-axis be in the interface plane. The wave has an incidence angle θ_i with respect the y-axis.

1. It was shown in class that if $c_1 < c_2$ and $\theta_i > \theta_c$, the transmitted wave is of the form

$$p_t = P_t \, e^{-k_x x} \, e^{i(k_y y - \omega t)}. \qquad (2)$$

Write the conditions for the continuity of the pressure and normal velocity across the interface. Give the expressions for the Rayleigh reflection and transmission coefficients (R, T, R_I, T_I) for the pressure and intensity.

2. Reproduce and plot the results of Figures 6.4.2-6.4.5.

III. A broadband plane wave at an angle of incidence of 45^o and propagating through air with sound speed of 340 m/s is reflected from a rigid plane surface. Over the octave band centered at 500 Hz the incident sound has nearly constant spectral density. The sound level corresponding to this band for the incident wave alone is 80 dB (re 20 μPa).

1. Determine and plot as a function of distance from the wall the octave band sound pressure level for the same band that results because of the sound reflection.
2. Beyond what minimum distance can one assume that the octave-band level is within ±0.5 dB of 83 dB?
3. How does this answer change if one considers instead an octave band centered at 250 or 1000 Hz?

IV. An incident acoustic wave of frequency $f = \omega/(2\pi)$ is propagating toward a plane surface specimen of absorbing material located at $y = 0$ at an angle of incidence of 45^O. The acoustic pressure (incident wave plus reflected wave) just outside the surface is

$$p = Acos[\omega(t - \frac{x-y}{2^{1/2}c})] - 0.5Asin[\omega(t - \frac{x+y}{2^{1/2}c})], \qquad (3)$$

where A is the amplitude of the incident wave and y the distance from the interface.

1. What is the specific acoustic impedance of this interface?
2. If the material is locally reacting, what will the absorption coefficient for reflection with the same frequency at normal incidence be?