P6317 Assignment II

Due, Wednesday, March 22, 2017

1) Consider sound travelling across an air-water interface. At the interface, the particle speed and the pressure must match.

   a) [5] For a given velocity (at the boundary), compare the pressure anomalies far from the interface in the air and in the water. Assume, $\rho_{air} = 1.39$ kg/m^3, $C_{air} = 335$ m/s, $\rho_{water} = 1000$ kg/m^3, and $C_{water} = 1500$ m/s.

   b) [5] Compare how a sound source designed for use in the air would perform if used underwater. And, how would a sound source designed for water perform if used in the air. Assume that the transducer drives the velocity at the transducer face at a fixed value whether in water or in air. How reasonable do you think the last assumption is (justify your answer).

2) a) [5] Twentyone sources are equally spaced over 2.0 m along the z axis. The sources have equal amplitudes (a/21), and signal frequency f = 15,000 Hz. Calculate and graph the source pattern far from the source over a range of $-.2 \leq \sin\phi \leq .2$.

   b) [5] Repeat the calculation and graph but this time assume a continuous distribution of sources of strength a/2 m^{-1}. Compare the two plots.

3) a) [8] For a typical ocean sound channel, the sound speed initially decreases with depth and then increases with depth so that the sound speed at the ocean bottom is greater than that at the surface. In this situation, the limiting rays that remain in the sound channel (without reflecting at the bottom or surface) are determined by those that are horizontal at the surface. Consider a source somewhere in the sound channel where the sound speed is $C_s = C(0) - \Delta C$ ($C(0)$ is the sound speed at the surface). For this source, demonstrate that the maximum angle that a ray can have with the horizontal and still remain trapped by the sound channel is given by,

$$\theta_{max} \simeq \sqrt{2\Delta C/C_s} \qquad (1)$$

   (Hint: use snells law, assume θ_{max}, and ΔC are small).

3) a) [2] How would Equation (1) be changed if the sound speed at the bottom was less than at the surface.

4) [10] Convergence zones occur when sound rays starting out at or near the surface, refract downward, through a sound channel and then back up to the surface. Consider a simplified sound speed profile where the sound channel axis is defined as depth $z = 0$ and for which the sound speed above and below can be described by the equations $C = C_0 + g'z$ and $C = C_0 - gz$ respectively, $z = h'$ at the surface, and $z = -h$ at the bottom, $C(h') = C_1'$, $C(h) = C_1$, and $C_1 > C_1'$.

For a source located at the surface, in terms of C and g, at what distance will the horizontal ray reappear at the surface. Evaluate the result numerically if $C_0 = 1475$ m/s, $C_1' = 1505$ m/s, $C_1 = 1530$ m/s, $h' = 400$ m, and $h = 3200$ m. (Recall that ray paths describe the arc of a circle in a constant sound speed gradient ocean).