

Lecture #2: Background

READINGS AND FIGURES

Readings: Instructor notes on boundary conditions

Frisk, Chapter 3, sections 3.1, 3.2 and 3.3 (up to Eq. 3.38.)

DESCRIPTION OF NOTES

Having the basic wave equation for ocean acoustics in hand, we now need to put together the rest of the pieces needed to solve for the acoustic field. This means looking at: 1) observables (not just pressure), 2) boundary conditions, and 3) some ancillary quantities (such as impedances, reflection coefficients, etc.) This material will be familiar to those who have had either a basic underwater acoustics course or a wave theory course that included some acoustics. However, even for those who have this background, a definition of terms and usages is needed, and so we will go through some further “basics” here, just for completeness.

The first part of the lecture, presented in my inimitable, sloppy handwriting, is a discussion of the acoustic field observables and potentials for them. In addition to a hydrophone sensing pressure, an accelerometer can sense (obviously!) accelerations, which once integrated over time gives velocity and twice integrated gives displacement. So pressure, velocity, and displacement are all very useful observables. Also, due to tangential stresses not affecting a fluid, all we need to worry about is the normal (longitudinal) wave component motions.

The first thing we see from the notes is that the pressure, displacement potential, and velocity potential are all proportional for fluids. So we can, if we are careful about the proportionality constants, talk about all these three quantities rather interchangeably.

The next handwritten notes section, “Boundary conditions”, discusses the fluid-fluid planar interface BC, which is needed for the layered medium treatment that is the usual first order approximation in ocean acoustics. The math, and the physical underpinnings of the boundary conditions, are all rather straightforward in this section. Following this, there is some discussion of the (pressure) reflection and transmission coefficients, which are also useful, and can be used as boundary conditions for some calculations. The discussion in this section of notes loosely follows from Clay and Medwin’s “Acoustical Oceanography.” (Reference in separate attachment.)

The next small class notes section concerns the “specific acoustic impedance.” In direct analogy to Ohm’s law, $E=I \cdot R$, the resistance of the acoustic medium to fluid flow (particle velocity) caused by the pressure perturbation is its resistance, or as a fully complex quantity, impedance. It is found that the impedance is simply ρc for a plane wave moving through a fluid. Sound doesn’t travel easily between media with a large “impedance mismatch” (difference), with air and water being a prime example.

The last part of Lecture #2 is taken from Frisk, Chapter 3, Sections 1,2,and 3 (partial) up to Eq. 3.38. This chapter, entitled "Plane wave reflection from planar boundaries", gives the rest of the boundary conditions we need, albeit restricted to the (very important) case of a plane wave. (We will see that reflection from other types of waves can be expressed as an expansion in plane waves, so this IS the most basic case.) The planar boundary is typical of the (smooth) sea surface, and a flat and horizontally stratified seabed, so again, this is an important case. Some discussion of the reflection coefficients is also included in this important section.

In section 3.2.1, Frisk states the "soft", or pressure-release boundary condition, $p=0$, which is the appropriate one for the sea surface. Strictly speaking, this implies that there is a hard vacuum above the water, but it is not a bad approximation – our measly 15 PSI of air pressure is trivial compared to water overburden pressures!

In section 3.2.2, Frisk states the "hard bottom" BC, for which the derivative of the pressure normal to the boundary vanishes. This is a rather crude, limiting case approximation to the water-sediment or sediment-basement BC's, but it is also an incredibly useful one for approximate calculations due to its simplicity.

One can also pose a boundary condition that is "intermediate" to the two above, called a "mixed" or impedance BC. Frisk shows this type in section 3.2.3. This type of BC is actually capable of representing reflection from a complex, fully layered medium, and finds wide use in ocean acoustics.

The above three boundary conditions are well known mathematically as the Dirichlet, Neumann, and Cauchy boundary conditions respectively.

The above BC's tell us what we need to know in the vertical (z-direction) for a horizontally layered medium. Now let's look in the horizontal direction.

Frisk's section 3.2.4, on the Sommerfeld radiation conditions, is one of the nicest, most concise descriptions of the BC at infinity that I have seen.

As to the source BC (the other boundary condition we need in the horizontal), it will be discussed in the next lecture, as it fits most naturally in the context of Green functions.

Section 3.3 of Frisk is a discussion of the simple law of reflection, familiar to all. Section 3.3.1 and 3.3.2 ($R=-1$ for a soft boundary and $R=1$ for a hard boundary) should be noted as simple, but very useful, results.

Section 3.3.3 starts by deriving another standard result, Snell's Law, and then transits to the Rayleigh reflection coefficient. Both are simple, but necessary, results to remember for what will follow.

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2.682 Acoustical Oceanography
Spring 2012

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