Term Project #1 – **Coupled Acoustic Normal Modes and Rough Surface Scattering**

In this project, there is a combination of both acoustic propagation and rough surface scattering. It is phrased loosely to some extent to encourage you to play around with the acoustic model and the parameters.

1) Create a program to make realizations of a rough sea surface for a hard bottom, isovelocity acoustic waveguide.
   a. Let's consider 6-10 second surface waves over a 10-20 km range in a 100m deep ocean. Take a "flat" power spectrum $S(\omega)$ for simplicity, with $\sigma^2 = 1\ m^2$.

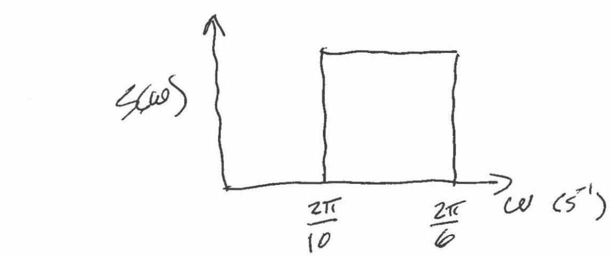

FIG 1.

The surface wave dispersion relation for deep water can be used, i.e. $\omega^2 = gk = {T^2}/{2\pi} = \lambda$. To create a realization is easy enough. We just break the spectrum

into N segments (say 40 for our four second wave period spread) and make each segment a sinusoid with a random phase (since the power spectrum "loses" the phase information). Thus we have

$$\xi(r) = \sum_{n=1}^{N} a_n(\omega_n) sin[k_n(\omega_n) r + \varphi_n^{rand}]$$

subject to

$\sum_n a_n^2 = \sigma^2$ and $\omega_n^2 = gk_n$ for the k_n.

This is very easy to implement, and should give a useful set of realizations. (Each realization is just a new set of random phases.) And if you don't like this surface, feel free to try your own spectrum or one of the classic surface wave spectra.

   b. Now that you have a surface, test it for various things: 1) gaussianty (using many realizations at one point), 2) ergodicity (using many range points for one realization), and 3) reasonable correlation length (which you can do both analytically from $S(\omega)$ and numerically from the surfaces you generate).

2) Adiabatic mode approximation

Next, let's look at a waveguide with c = 1500 m/s and H = 100m which has 3-4 trapped modes in it. You will need to play with the acoustic frequency but our class notes (and Frisk) provide a very good first guess.

a. Using adiabatic modes, and choosing some realization of the rough surface, create a 2-D (x-z plane) color picture of the acoustic intensity (dB units) over 10-20 km. Contrast this with the same calculation, but with a smooth surface. You have freedom of choice in the source depth – feel free to jiggle it and see what happens.
b. For the adiabatic mode solution, plot the I(r,z) (in dB) results for your rough and smooth surfaces at one receiver depth (source depth fixed as before). See if you can observe the decrease in the coherence in the scattered case via the smaller peak-to-null distance.

3) Fully Coupled Modes

a. Using the Katznelson and Petnikov (K&P) notes from class on the "first order coupled equations," create a fully coupled normal mode program for our hard bottom waveguide. This will mean figuring out how to solve a system of first order coupled equations – should be old knowledge, and not too hard!

b. Plot the mode coupling coefficients for a given realization. Are they large or small, i.e., is the system adiabatic or coupled. Does close coupling hold?

c. Plot I(z, r) in dB at one receiver depth (as above) and compare to the no coupling and adiabatic runs.