13.42
DESIGN PRINCIPLES FOR OCEAN VEHICLES

Spring 2003 – Lab #1
Wave Spectra

1 Introduction

All the lab sessions will be conducted at the Ocean Engineering Testing Tank Facility (Tow tank).

This first lab will reiterate the the concepts of phase velocity, group velocity, and the dispersion relation and to investigate multiple frequency waves. The Bretschneider wave spectrum will be input to the wave maker and the resulting waves recorded. Wave measurements will be analyzed to look at the spectrum.

Working in groups, you will use the human eye as well as wave probes to make appropriate measurements as detailed below. You will need a notebook to log the parameters of your data runs. The data will be placed in the Course locker and accessed through the course web page. You will be using MATLAB to analyze and plot the data you obtain.

For this lab you will need to use the wavemaker of the tow tank. Directions for its use will be provided during the lab sessions. Your completed report should include a description of the experimental set-up, data plots, answers to the questions printed in italics, and a general discussion of your results and conclusions. Each of you should hand in your own report, but given the group effort required to perform the experiments and the increased understanding gained through discussion, collaboration with your lab partners is encouraged.

1.1 Towtank Equipment

The towtank is one of Ocean Engineering's hydrodynamic test facilities. The main tank is 120' long (working length is 100 feet) x 8' wide x 5' deep. You will be using its wave paddle, wave height probes, and its data collection computers. Please be advised that it is a working research laboratory, and has *fragile equipment* around which is in use by researchers.

2 Preliminaries

For this lab, you will be asked to calibrate the wave probes and create single frequency, two frequency and multiple frequency content waves.

In your lab write up (experimental setup) you should *explain why three wave probes are being used and why they are spaced as they are. (Hint: Consider the probe spacing in relation to the wave lengths we are using and the propagation characteristics of the group and phase velocities we are trying to measure.) Which spacing makes it relatively easy to measure which velocity accurately? What is the maximum possible separation of the closely spaced probes which will allow us to measure the characteristics of waves with frequencies between 1 and 2 Hz.*

3 Single Frequency Wave Packets

Take a few minutes to familiarize yourself with the controls of the wavemaker. Generate a few cycles and make sure you can turn it on and off to generate a wave packet of the desired frequency and amplitude.

Generate one or two wave packets with amplitude and frequency of your choice.

Refer to the table taped to the wave maker controls for acceptable frequency and amplitude combinations in order to avoid creating standing waves or hitting the resonant frequency of the wave paddle.

Make sure your wave packets fit in the tank (approximately 5 seconds of running the wavemaker should be sufficient). You are welcome to generate the packet several times in an effort to get a clean run, practice your technique, or otherwise increase your confidence in the results.

Record the outputs of the wave probes for each run on the computer with DASY LAB (detailed operating instructions for the data collection system will be supplied in the control room). Make sure you record the wave parameters of each file in your notebook. The data file will consist of four columns of data: the time tag and the voltage outputs from the three wave probes. Use the results of the wave probe calibration to plot wave amplitude vs. time for the three probes on a single plot for each packet. From this information determine the phase and group velocities for each frequency. You can work from the plots to get a rough answer, but looking at the amplitude data or blowing up selected portions of the plots will be more accurate.

Observe the wave packets you create. You will notice that wave crests appear at the back of the group, propagate to the front, and disappear. The crest is moving at the phase velocity for the frequency of that packet. The front and back of the packet are moving at the group velocity.

In your report discuss:

1. *For each frequency, construct a plot of the three time series of wave amplitude from the wave probes to show the time delays between the arrivals of the wave packet.*

2. *Calculate the phase speed and group speed of the wave packet. Is the ratio of these two values what is predicted by theory? Comment on any discrepancies between theory and experiment.*

4 A Wave Packet Containing Multiple Discrete Frequencies

A computer routine called "twofrq.dat" has been prepared for you that will generate a wave packet containing 1 Hz and 2 Hz components. Set the amplitude dashpot to 3.0. Run the program and observe the results. Record the packet as it passes the first wave probe. (You may want to make a second run with a longer group to generate a clean spectrum for the third question below. Make sure you understand why this will be helpful.) Answer the following questions and turn in any plots:

1. *What did you observe in a qualitative sense? Did the waves separate? Which wave was in front? Does this make sense?*

2. *Plot the time trace of the recorded data for each of the three wave probes. Is there a difference between probe 1 and 3? Discuss what you observe in context of what we know about waves, phase speed and group speed. Calculating phase and group speed for waves at 1 and 2 Hz may be of use.*

3. *Use the MATLAB functions "spectrum" and "specplot" on the wave amplitude data. You should see the 1 Hz and 2 Hz components of the packet in the resulting spectrum. Qualitatively explain why there are strong contributions to the spectrum at frequencies other than 1 Hz and 2 Hz. What change in the experiment does this suggest to make the 1 Hz and 2 Hz components stand out more clearly in the spectrum?*

4. *Consider a hypothetical wave packet composed of 4 distinct frequencies (1, 1.4, 1.7, and 2 Hz). Qualitatively sketch the time series for a wave probe that is positioned "a long distance" from the wavemaker.*

You should now have a good understanding of the physical ramifications of the dispersion relation for the case of a discrete power spectrum. Note that each of the four packets of section 3 are discrete as well: each is composed of a single frequency. You can use MATLAB to view their power spectrums if you are curious.

5 A Continuous Spectrum Wave

The last part of this lab session will deal with wave packets that have continuous power spectra. A computer routine generates random ocean waves using the standard Bretschneider spectrum as discussed in class. Set the amplitude dashpot to 2.29. Run the program and record the wave height using the wave probes. Answer the following questions and turn in any plots:

1. *Plot Wave Amplitude vs. Time from your data. It should look fairly random.*

2. *Use the MATLAB functions "spectrum" and "specplot" to get the output spectrum (you may compare your plot with the plot of the Brechtshcneider spectrum in figure 2 in p. 4.41 of the class notes)*

3. *Calculate the significant wave height of the waves using the data obtained at wave probe 1 or 2.*

4. *If the tow tank was "much" longer, what would you observe in a qualitative sense sitting at the "beach" end?*

6 MATLAB

MATLAB will come in handy for processing the lab data. There are four functions placed in the folder *http://web.mit.edu/13.42/www/labs/code*; they can also be downloaded from the course webpage. The functions are:

- 'wavedata.m' - reads data file and calibration file, and outputs wave statistics
- 'cal3.m' - read calibration data and creates calibration file 'cal.mat'
- 'parsedl2.m' - imports numbers from raw data file created by DasyLab
- 'specplot.m' - standard Matlab function used for spectral analysis

The function 'wavedata.m' prompts you to select a data file, and then uses the file 'cal.mat', which you must produce by running 'cal3.m', and the function 'parsedl2.m' to generate a matrix containing calibrated and scaled data from all three wave probes. It then calculates wave statistics using that matrix and some graphical user input. You are responsible for either writing code or modifying what we've given you in order to generate the plots and analysis needed for the lab writeup.

7 Closing Comments

- Sample MATLAB code is posted on the lab page of the 13.42 website. This is the code used in 13.021 labs and may need to be modified for this lab. But it will serve as a guide for processing your data.
- Be sure to have the lab supervisor transfer your data to the course locker. You should have a .i32 file for each run you generate and also the calibration.

Your lab report should be formatted similar to a technical paper, with an abstract, introduction, and experimental setup (including calibration methods), results and discussion sections. Keep the report clear and concise but be sure to answer all the questions above. Each student should hand in an individual lab report. Collaboration in processing the data is encouraged.