COMPUTER PROGRAM FOR REFRACTION OF DIRECTIONAL RANDOM WAVES

by

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ABSTRACT

A computer program called **RESHOAL** is presented in this report. **RESHOAL** computes the directional random wave spectrum in specified shallow water depth for given incident directional random wave spectrum in deeper water depth using linear finite-depth theory for straight shorelines with parallel bottom contours. To minimize the required input, the incident directional random wave spectrum is assumed to be given by the product of the *TMA* frequency spectrum and the Mitsuyasu-type directional spreading function. The input parameters for the *TMA* spectrum are the water depth, the spectral estimate of the significant wave height, the spectral peak period, and the peak enhancement factor for the spectral shape. The input parameters for the directional spreading function are the dominant incident wave direction and the maximum value of the spreading parameter.

The output of **RESHOAL** includes the directional random wave spectrum, the refracted frequency spectrum, and the directional energy distribution function in specified shallower water depth. The corresponding shoaled uni-directional frequency spectrum is also computed to quantify the effects of directional spreading and oblique incidence. The spectral parameters computed from the incident, refracted, and shoaled uni-directional frequency spectra include the spectral estimates of the different wave heights and periods as well as the parameters related to the spectral shape. The directional energy distribution function is used to compute the dominant wave direction and the degree of wave energy spreading about the dominant wave direction. In addition, the time series corresponding to the computed frequency spectra are generated numerically using a random phase scheme. The generated time series are analyzed using a

zero up-crossing method. The ouput parameters from the computed time series include various wave heights and periods as well as the parameters related to wave grouping. The individual zero up-crossing waves are compared with an empirical criterion of regular wave breaking to ensure that no wave breaking will occur in the specified shallow water depth since the linear finite-depth theory employed herein is not applicable for breaking waves.

Finally, an equivalent uni-directional frequency spectrum is computed to generate the shoaled uni-directional frequency spectrum in a two-dimensional wave flume that will be equivalent to the refracted frequency spectrum in the specified shallow water depth as long as the linear finite-depth theory is valid. An example is given to show the use of the computed equivalent uni-directional frequency spectrum in order to account for the effects of directionality and refraction in a two-dimensional experiment.

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

The design of a coastal structure requires the determination of design wave conditions at the site of the structure, while available wave data is typically situated in relatively deep water (e.g., 10 m depth). Consequently, analyses of irregular wave transformation into the nearshore region will be necessary. The effects of directional spreading of incident irregular waves are generally not considered in such analyses. Relatedly, hydraulic model tests for the design of a coastal structure are typically performed in a two-dimensional wave flume since three-dimensional model tests are time consuming and expensive. The two-dimensional tests do not account for the effects of directional spreading unless wave conditions in front of the structure are reproduced approximately considering the refraction and shoaling of directional random waves.

For the restricted case of a straight shoreline with parallel bottom contours, linear finite-depth theory (Longuet-Higgins 1957; LeMéhauté and Wang 1982) may be applied to predict the refraction and shoaling of directional random waves with little computational effort. This theory has been shown to be reasonably accurate except that it does not predict the generation of higher and lower harmonics due to nonlinear wave-wave interactions (Elgar and Guza 1985; Freilich *et al.* 1990; Abreu *et al.* 1992). It is noted that nonlinear theories for directional random waves are available but require considerable computational efforts. Kobayashi and Wurjanto (1992) applied this theory to estimate the incident random waves immediately seaward of the breaker zone which were used as input to the numerical model **RBREAK** for predicting irregular wave setup and run-up on natural beaches. The computer program **RESHOAL** presented in this report is an expanded version of the computer program used by Kobayashi and Wurjanto (1992) to allow more routine applications of linear finite-depth theory for the refraction and shoaling of directional random waves incident on straight shorelines with parallel bottom contours.

1.2 OUTLINE OF REPORT

This report is written in such a way that users should be able to run **RESHOAL** without knowing the details of the computer program **RESHOAL** listed in Appendix A. Chapter 2 concisely explains the equations and numerical procedures used in **RESHOAL**. Chapter 3 explains the computer program **RESHOAL** in detail, although the listed computer program is written in a self-explanatory manner. The additional explanations will facilitate usage of **RESHOAL** and modifications of **RESHOAL** by users if necessary.

Appendix B presents computed examples corresponding to Run 1 in the paper of Kobayashi and Wurjanto (1992) who used an earlier version of **RESHOAL** to compute the incident random waves immediately seaward of the breaker zone. **RESHOAL** based on linear finite-depth theory is not applicable inside the surf zone. The computed incident random waves were used as input to the numerical model **RBREAK** which is applicable for breaking and broken waves. **RBREAK** can not predict shoaling of nonlinear shallow-water waves over a long distance without wave breaking as explained by Kobayashi *et al.* (1989). The combined use of **RESHOAL** and **RBREAK** will hence be necessary for the design of coastal structures located inside the surf zones if design waves are specified in relatively deep water.

Appendix C presents an example of the applications of **RESHOAL** to a laboratory experiment in a two-dimensional wave flume. In this example, directional random waves specified at the location of a wave maker are shoaled and refracted using **RESHOAL**. The refracted frequency spectrum at specified shallower water depth is computed from the refracted directional random waves. The equivalent uni-directional frequency spectrum at the location of the wave maker is then computed from the refracted frequency spectrum. Linear uni-directional random waves generated using this equivalent frequency spectrum in a two-dimensional wave flume will result in the shoaled uni-directional frequency spectrum that will be the same as the refractred frequency spectrum at the specified shallower depth provided other factors such as nonlinearity and dissipation are negligible.

Appendix D explains the contents of the disk accompanying this report as well as the computation time for each of the examples included in this report.

Chapter 2

MATHEMATICAL FORMULATION

2.1 GOVERNING EQUATION

Linear finite-depth theory for computing the shoaling and refraction of directional random waves incident on straight shorelines with parallel bottom contours can be expressed as (LeMéhauté and Wang 1982)

$$S_2(f,\theta_2) = \frac{C_1(Cg)_1}{C_2(Cg)_2} S_1(f) G_1(f,\theta_1) = \frac{k_2}{k_1}\frac{(Cg)_1}{(Cg)_2} S_1(f) G_1(f,\theta_1) \tag{2.1}$$

with

$$\theta_1 = \sin^{-1}\left(\frac{k_2}{k_1}\sin\theta_2\right) \tag{2.2}$$

where

$S(f,\theta)$ = directional wave spectrum $(s \cdot m^2)$

$S(f)$ = frequency spectrum $(s \cdot m^2)$

$G(f,\theta)$ = directional spreading function defined as $G(f,\theta) = S(f,\theta)/S(f)$

C = phase velocity = $\frac{2\pi f}{k}$ (m/s)

Cg = group velocity = $\frac{C}{2}\left[1 + \frac{2kh}{\sinh(2kh)}\right]$ (m/s)

f = frequency (Hz)

θ = wave direction (rad) with $\theta = 0$ for normal incidence

h = water depth (m)

k = wave number (1/m)

computed from the linear dispersion relationship

$$kh\tanh(kh) = h(2\pi f)^2/g \tag{2.3}$$

In this report, the subscript 1 denotes the deeper water depth where the incident directional waves are specified, while the subscript 2 indicates the shallower water depth where the refracted directional waves are predicted.

2.2 COMPUTATIONAL DOMAINS

The frequency, time and angle are discretized in the following manners to reduce the number of input parameters. The maximum frequency, f_{max}, and the number of data points, NP, are selected from the following criterion:

$f_{max} = 1/(2\Delta t) = 10/T_p$ with $\Delta t = T_p/20$

$NP = t_{max}/\Delta t = 4000$ with $t_{max} = 200T_p$

where

T_p = incident wave spectral peak period (s)

Δt = time step or sampling interval (s)

t_{max} = duration of generated time series (s).

The corresponding number of discrete frequencies within the frequency domain is

$$NF = \frac{NP+2}{2} = 2001. \tag{2.4}$$

Setting the minimum frequency $f_{min} = 0$, the frequency band width Δf and the discrete frequency f_j are computed

$$\Delta f = \frac{f_{max} - f_{min}}{NF - 1} \tag{2.5}$$

$$f_j = f_{min} + (j-1)\Delta f \tag{2.6}$$

where the subscript $j = 1, 2, 3, ..., NF$ and $f_{min} = 0$. Similarly, the time level t_n is given by

$$t_n = t_{min} + (n-1)\Delta t \tag{2.7}$$

with

$$\Delta t = \frac{1}{2f_{max}} \tag{2.8}$$

where the subscript $n = 1, 2, 3..., NP$ and $t_{min} = 0$. It is noted that the time series are assumed to be periodic with the period t_{max}. The directional domain ranges from $\theta_{min} = -90°$ to $\theta_{max} = 90°$. Specifying the number of discrete angles as $ND = 181$, the directional bandwidth $\Delta\theta$ and discretized wave direction θ_i are given by

$$\Delta\theta = \frac{\theta_{max} - \theta_{min}}{ND - 1} = 1° \tag{2.9}$$

$$\theta_i = \theta_{min} + (i - 1)\Delta\theta \tag{2.10}$$

where the subscript $i = 1, 2, 3, ..., ND$.

2.3 INCIDENT FREQUENCY SPECTRUM

The incident frequency spectrum in the deeper water depth is assumed to be given by the *TMA* spectrum (Bouws *et al.* 1985)

$$S_1(f) = S_{TMA}(f) = S_J \Phi_K. \tag{2.11}$$

The transformation factor Φ_K extending the JONSWAP spectrum to the finite depth h_1 is expressed as

$$\Phi_K = \tanh^2(k_1 h_1)\left[1 + \frac{2k_1 h_1}{\sinh(2k_1 h_1)}\right]^{-1}. \tag{2.12}$$

The JONSWAP spectrum S_J for wind waves in deep water is given by

$$S_J = S_P(f)\Phi_{PM}(f/f_p)\Phi_J(f, f_p, \gamma, \sigma) \tag{2.13}$$

with

$$S_P(f) = \alpha g^2 (2\pi)^{-4} f^{-5} \tag{2.14}$$

$$\Phi_{PM}(f/f_p) = \exp\left[(-5/4)(f/f_p)^{-4}\right] \tag{2.15}$$

$$\Phi_J(f, f_p, \gamma, \sigma) = \exp\left\{ \ln(\gamma) \exp\left[-(f - f_p)^2/(2\sigma^2 {f_p}^2)\right]\right\} \tag{2.16}$$

$$\sigma = \begin{cases} \sigma_a = 0.07 & f_p \geq f \\ \sigma_b = 0.09 & f_p < f \end{cases} \tag{2.17}$$

where

$\alpha =$ variable coefficient related to the spectral estimate of the significant wave height H_{mo} at the deeper water depth h_1

$g =$ gravitational acceleration

$f_p =$ spectral peak frequency at the deeper water depth h_1

$\sigma =$ variable coefficient assumed to be given by the standard values in (2.17)

The peak enhancement factor γ may range from 1 to 7 with a mean of 3.3. The value of γ will need to be determined using site-specific wave data. It is noted that the *TMA* spectrum is limited to wind waves and does not include infragravity waves (*e.g.*, Elgar *et al.* 1992).

The Bretschneider-Mitsuyasu spectrum in deep water (Goda 1985) is expressed as

$$S_1(f) = 0.257 H_s^2 T_s (T_s f)^{-5} \exp\left[-1.03 (T_s f)^{-4}\right] \tag{2.18}$$

where H_s and T_s are the significant wave height and period. Goda assumed in (2.18) that $H_s = H_{mo}$ and $T_s = T_p/1.05$ and (2.18) is rewritten as

$$S_1(f) = 0.312 H_{mo}^2 T_p (T_p f)^{-5} \exp\left[-1.25 (T_p f)^{-4}\right] \tag{2.19}$$

The *TMA* spectrum given by (2.11) reduces to (2.19) for $\gamma = 1$ and $\Phi_K = 1$. The computer program **RESHOAL** allows for the specification of the incident frequency spectrum $S_1(f)$ using (2.11) for any value of γ including $\gamma = 1$. To include the case of deep water in (2.11), an option is provided to specify $\Phi_K = 1$ by specifying **IDEEP** = 1 as input.

2.4 DIRECTIONAL SPREADING FUNCTION

The Mitsuyasu-type spreading function $G_1(f,\theta_1)$ at the deeper water depth h_1 as given by Goda (1985), is assumed in this report

$$G_1(f,\theta_1) = \frac{S_1(f,\theta_1)}{S_1(f)} = G_o(f)\cos^{2s(f)}\left(\frac{\theta_1 - \alpha_p}{2}\right) \tag{2.20}$$

where α_p is the predominant incident wave direction relative to the axis of $\theta = 0$ normal to the straight shoreline and ranges from $-\pi/2$ to $\pi/2$. The spreading parameter $s(f)$ and the normalization parameter $G_o(f)$ are expressed as

$$s(f) = \begin{cases} s_{max}(f/f_p)^5 & f \leq f_p \\ s_{max}(f/f_p)^{-2.5} & f > f_p \end{cases} \tag{2.21}$$

$$G_o(f) = \frac{1}{\pi}2^{2s-1}\frac{\Gamma^2(s+1)}{\Gamma(2s+1)} \tag{2.22}$$

where s_{max} denotes the maximum value of s at $f = f_p$. Field observations indicate that $s_{max} \simeq 10$ for wind waves and $s_{max} \simeq 25 - 75$ for swells (Goda 1985). Γ denotes the gamma function (Press *et al.* 1986). It is noted that (2.20) was defined in the range $-\pi \leq (\theta_1 - \alpha_p) \leq \pi$ which included waves propagating seaward. In this report, all the waves are assumed to propagate landward with the corresponding range $-\pi/2 \leq \theta_1 \leq \pi/2$ in relation to (2.9) and (2.10). This will not cause any problems provided G_1 is negligible in the ranges $(-\pi + \alpha_p) \leq \theta_1 < -\pi/2$ and $\pi/2 < \theta_1 \leq (\pi + \alpha_p)$. Combining the incident frequency spectrum $S_1(f)$ and the directional spreading function $G_1(f,\theta)$, the incident directional spectrum is given by

$$S_1(f,\theta_1) = S_1(f)G_1(f,\theta_1) \tag{2.23}$$

which has been used in (2.1).

2.5 ENERGY DISTRIBUTION FUNCTION

The directional energy distribution function may be defined as

$$D(\theta) = \int_{f_{min}}^{f_{max}} S(f,\theta)df \tag{2.24}$$

where $f_{min} = 0$ and f_{max} has been given in Section 2.2. The directional spectrum $S(f, \theta)$ is $S_1(f, \theta_1)$ given by (2.23) or $S_2(f, \theta_2)$ computed by (2.1). The functions $D_1(\theta_1)$ and $D_2(\theta_2)$ at the corresponding water depths h_1 and h_2 are used to examine the energy distributions with respect to the wave direction.

2.6 SHOALING OF UNI-DIRECTIONAL RANDOM WAVES

Uni-directional waves propagating at normal incidence to the shoreline, such as irregular waves generated in a two-dimensional wave flume, undergo shoaling only. The frequency spectrum at the shallower water depth h_2 for uni-directional, normally-incident waves is given by (*e.g.* Goda 1985)

$$S_2^u(f) = \frac{(Cg)_1}{(Cg)_2} S_1(f) \tag{2.25}$$

where Cg = group velocity and $S_1(f)$ is assumed to be given by (2.11).

2.7 REFRACTION OF DIRECTIONAL RANDOM WAVES

The refracted directional wave spectrum at the shallower water depth h_2 is computed by (2.1) which is rewritten as

$$S_2(f, \theta_2) = \frac{k_2}{k_1} \frac{(Cg)_1}{(Cg)_2} S_1(f, \theta_1). \tag{2.26}$$

For the computation of $S_2(f, \theta_2)$, θ_2 is discretized uniformly and the corresponding value of θ_1 is calculated from (2.2). Since $|\sin\theta_1| \leq 1$, $S_2(f, \theta_2)$ is set equal to zero when $(k_2 \sin\theta_2 / k_1) > 1$.

The refracted frequency spectrum at the shallower water depth h_2 is computed from the refracted directional spectrum

$$S_2(f) = \int_{\theta_{min}}^{\theta_{max}} S_2(f, \theta_2) d\theta_2. \tag{2.27}$$

The refracted energy distribution function $D_2(\theta_2)$ is calculated using (2.24) with $S(f,\theta) = S_2(f,\theta_2)$. The predominat wave direction at the shallower water depth h_2 is assumed to be the direction where $D_2(\theta_2)$ is the maximum.

2.8 SPECTRAL PARAMETERS

The spectral parameters associated with the frequency spectra, $S_1(f), S_2^u(f)$, and $S_2(f)$, represented by $S(f)$ in the following are computed using the subroutine **SPCPAR** written by Cox *et al.* (1991) and modified herein. These parameters are also explained in Goda (1985) except for the spectral correlated parameter κ (Battjes and van Vledder, 1984; Liu *et al.*, 1993) and summarized in the following for convenience.

The n-th spectral moment of $S(f)$ with $n = 0, 1, 2$ and 4 is computed from

$$m_n = \int_{f_{min}}^{f_{max}} f^n S(f) df. \tag{2.28}$$

The following spectral parameters are computed:

- Spectral width parameter based on m_2 and m_4:

$$\epsilon = \left[1 - \frac{m_2^2}{m_0 m_4}\right]^{1/2} \tag{2.29}$$

- Spectral width parameter based on m_1 and m_2:

$$\nu = \left[\frac{m_0 m_2}{m_1^2} - 1\right]^{1/2} \tag{2.30}$$

- Spectral peakedness parameter:

$$Q_p = \frac{2}{m_0^2} \int_{f_{min}}^{f_{max}} f \left[S(f)\right]^2 df \tag{2.31}$$

- Standard deviation of free surface displacement:

$$\eta_{\mathrm{rms}} = \sqrt{m_0} \tag{2.32}$$

- Root-mean-square wave height:

$$H_{\mathrm{rms}} = \sqrt{8m_0} \tag{2.33}$$

- Significant wave height:

$$H_{\mathrm{mo}} = 4.004\sqrt{m_0} \tag{2.34}$$

- Mean period based on m_1:

$$T_{01} = \frac{m_0}{m_1} \tag{2.35}$$

- Mean period based on m_2:

$$T_{02} = \sqrt{\frac{m_0}{m_2}} \tag{2.36}$$

- Spectral Correlated Parameter:

$$\kappa = \frac{1}{m_0}\left\{\left[\int_{f_{min}}^{f_{max}} S(f)cos(2\pi f T_{02})df\right]^2 + \left[\int_{f_{min}}^{f_{max}} S(f)sin(2\pi f T_{02})df\right]^2\right\}^{1/2} \tag{2.37}$$

In addition, the spectral peak period T_p and the spectral peak frequency $f_p = 1/T_p$, where $S(f)$ is the maximum at $f = f_p$, are given as output. The predominant wave direction corresponding to the maximum value of $D(\theta)$ given by (2.24) is also given as output along with the aforementioned spectral parameters.

2.9 TIME SERIES GENERATION AND PARAMETERS

For the specified or computed frequency spectrum $S(f)$ the corresponding free surface displacement $\eta(t)$, as a function of time t for the duration $0 \leq t \leq t_{max}$, is generated using the random phase scheme as explained by Cox *et al.* (1991). The generated time series $\eta_n = \eta(t_n)$, where t_n with $n = 1, 2, 3, ..., NP$ given by (2.7), is analyzed using the zero-upcrossing method as described by Cox *et al.* (1991). The zero-upcrossing wave height and period, denoted by H_i and T_i with $i = 1, 2, 3, ..., N_o$, are obtained for N_o individual waves. The individual waves are also ranked in descending order of H_i. The wave height and period of the r-th ranked wave are denoted by H_r and T_r, respectively.

The following time series parameters are given as output using the subroutine **TIMPAR** given by Cox *et al.* (1991) and modified herein:

- Mean water level:

$$\overline{\eta} = \frac{1}{NP}\sum_{i=1}^{NP}\eta_i \tag{2.38}$$

- Standard deviation of free surface displacement:

$$\eta_{\text{rms}} = \left[\frac{1}{NP}\sum_{i=1}^{NP}(\eta_i - \overline{\eta})^2\right]^{1/2} \tag{2.39}$$

- Number of zero-upcrossing waves:

$$N_o = \frac{t_{max}}{\overline{T}} \tag{2.40}$$

- Average wave height:

$$\overline{H} = \frac{1}{N_0}\sum_{i=1}^{N_0}H_i \tag{2.41}$$

- Average wave period:

$$\overline{T} = \frac{1}{N_0}\sum_{i=1}^{N_0}T_i \tag{2.42}$$

- Root-mean-square wave height:

$$H_{\text{rms}} = \left[\frac{1}{N_0}\sum_{i=1}^{N_0}H_i^2\right]^{1/2} \tag{2.43}$$

- Significant wave height:

$$H_s = \frac{3}{N_0}\sum_{r=1}^{N_0/3}H_r \tag{2.44}$$

- Significant wave period:

$$T_{\text{S}} = \frac{3}{N_0}\sum_{r=1}^{N_0/3}T_r \tag{2.45}$$

- Average height of the one-tenth highest waves:

$$H_{10} = \frac{10}{N_0}\sum_{r=1}^{N_0/10}H_r \tag{2.46}$$

- Average period of the one-tenth highest waves:

$$T_{10} = \frac{10}{N_0} \sum_{r=1}^{N_0/10} T_r. \tag{2.47}$$

In addition, the run length of wave groups is computed. The run length is equal to the number of individual waves in a sequence for which the wave heights are greater than a specified wave height (Goda 1985). This wave height is taken to be the significant wave height H_s herein. The mean run length $\bar{j}$ is defined as

$$\bar{j} = \frac{1}{NK} \sum_{j=1}^{NK} LRN(j) \tag{2.48}$$

where NK = number of runs obtained from N_o wave heights; and $LRN(j)$ = run length of wave heights exceeding H_s. A large mean run length implies that wave heights exceeding H_s appear in groups rather than individually.

2.10 WAVE BREAKING

The linear finite-depth theory used in (2.1) will not be appropriate inside the surf zone since the linear theory does not include wave energy dissipation due to wave breaking. Kobayashi and Wurjanto (1992) used an approximate method based on the empirical criterion of regular wave breaking to ensure that individual waves in the irregular wave train would not break at the shallower water depth h_2. For the r-th ranked wave whose wave period is T_r, the corresponding breaker height H_b may be estimated using the empirical criterion proposed by Goda (1985), although other criteria may also be applied

$$H_b = 0.17 L_o \left\{ 1 - \exp\left[-1.5 \frac{\pi h_2}{L_o} (1 + 15 m^{4/3}) \right] \right\} \tag{2.49}$$

with

$$L_o = \frac{g T_r^2}{2\pi} \tag{2.50}$$

where m = the bottom slope at the shallower water depth h_2. The r-th ranked wave may be assumed to be breaking or broken if its wave height $H_r \geq H_b$. It should be emphasized that the proposed procedure may not be very accurate since the individual waves in the irregular wave train are not regular waves and the empirical criterion expressed by (2.49) is applicable for regular waves only.

2.11 EQUIVALENT UNI-DIRECTIONAL FREQUENCY SPECTRUM

One way to account for the effects of refraction of directional random waves in a two-dimensional wave flume is to generate an equivalent uni-directional frequency spectrum in the wave flume which will result in the refracted frequency spectrum $S_2(f)$ at the shallower depth h_2 instead of the shoaled uni-directional frequency spectrum $S_2^u(f)$. The equivalent uni-directional frequency spectrum may be generated in any depth greater than h_2. For simplicity, the equivalent uni-directional frequency spectrum is assumed to correspond to the deeper water depth h_1 and is expressed as

$$S_1^e(f) = \frac{(Cg)_2}{(Cg)_1} S_2(f). \tag{2.51}$$

Linear uni-directional random waves generated using $S_1^e(f)$ at the water depth h_1 will result in the shoaled uni-directional frequency spectrum that should be the same as $S_2(f)$ provided other factors such as nonlinearity and dissipation are negligible.

It should be noted that two-dimensional hydraulic model tests using (2.51) may be justified if the directional energy distribution function $D_2(\theta_2)$ at the shallower depth h_2 is essentially zero except for the very narrow range around $\theta_2 = 0$, corresponding to normal incidence.

Chapter 3

COMPUTER PROGRAM RESHOAL

3.1 INTRODUCTION

The computer program **RESHOAL**, attached in Appendix A, consists of the main program and 21 primary subroutines. The program has been tested on the IBM 3090 running under VM/XA. The program is written in FORTRAN-77 and should run on other systems. Also, **RESHOAL** is written using the SI units for which the gravitational acceleration $g = 9.81m/s^2$. Replacing $g = 9.81m/s^2$ by $g = 32.2ft/s^2$ in the program allows the user to use English units.

RESHOAL is described in detail in the following sections. To minimize the number of input parameters associated with various options, **RESHOAL** computes the entire scope of the program including the shoaling of uni-directional random waves, the refraction of directional random waves, spectral and time series parameters and wave breaking statistics. The typical computation time for each run made in this report was several minutes and the minimization of the computation time is regarded to be secondary. **RESHOAL** is written in a self-explanatory manner to allow modifications without difficulties if necessary.

3.2 INPUT DATA FILE

The execution of **RESHOAL** requires the user to supply one input data file. The progam offers the user the freedom to specify the file name, however, the length of the name is limited to 13 characters. The preparation of the input data file is described in Section 3.6.

3.3 MAIN PROGRAM

The main program lists the parameters and variables contained in the **COMMON** blocks, which are detailed in Section 3.5., and coordinates the computational procedures executed by the subroutines. The procedures can be separated into the following tasks and are explained below:

1. Groundwork.
2. Spectral Calculations.
3. Time Series Calculations.
4. Wave Breaking Calculations.
5. Output and Graphing.

3.3.1 GROUNDWORK

The preliminary tasks performed include

- Reading the input data file.
- Discretization of frequency, direction and time domains as explained in Section 2.2.
- Calculating the wave numbers and their ratios in (2.1), (2.2) and (2.26).
- Calculating the ratios of the group velocities in (2.1), (2.25) and (2.26).

3.3.2 SPECTRAL CALCULATIONS

The following spectral calculations are performed:

1. Incident Frequency Spectrum $S_1(f)$ at deeper depth h_1 given by (2.11).
2. Incident Directional Spectrum $S_1(f, \theta_1)$ at deeper depth h_1 given by (2.23).
3. Directional Energy Distribution Function $D_1(\theta)$ at deeper depth h_1 given by (2.24) using $S_1(f, \theta_1)$.
4. Shoaled Uni-Directional Frequency Spectrum $S_2^u(f)$ at shallower depth h_2 given by (2.25).
5. Frequency Spectrum $S_2(f)$ at shallower depth h_2 given by (2.27).
6. Refracted Directional Spectrum $S_2(f, \theta_2)$ at shallower depth h_2 given by (2.1) and (2.26).
7. Directional Energy Distribution Function $D_2(\theta)$ at shallower depth h_2 given by (2.24) using $S_2(f, \theta_2)$.
8. Equivalent Uni-Directional Frequency Spectrum $S_1^e(f)$ at deeper depth h_1 given by (2.51).
9. Spectral parameters explained in Section 2.8 for the frequency spectra $S_1(f)$, $S_2^u(f)$ and $S_2(f)$.

3.3.3 TIME SERIES CALCULATIONS

The following time series calculations are performed:

1. Three time series corresponding to the three frequency spectra $S_1(f)$, $S_2^u(f)$, and $S_2(f)$ using the random phase scheme.

2. The time series parameters explained in Section 2.9 for the three time series generated numerically.

3.3.4 WAVE BREAKING CALCULATIONS

For the ranked wave heights and periods computed from the three time series, the breaking criterion for the ranked individual waves is evaluated as explained in Section 2.10.

3.3.5 OUTPUT AND GRAPHING

Six output data files are created and used for storing and tabulating the following information:

1. Input Parameters.
2. Spectral Parameters.
3. Time Series Parameters.
4. Ranked Waves and Breaker Heights for Shoaled Uni-Directional Frequency Spectrum.
5. Ranked Waves and Breaker Heights for Frequency Spectrum of Refracted Directional Waves.
6. Run Length Statistics.

Fourteen output data files are created and used for the purposes of plotting the following figures:

1. Incident, Shoaled and Refracted Frequency Spectra versus Frequency.

2. Energy Distribution Functions at depths h_1 and h_2 versus Direction.

3. Time Series of Free Surface Displacement for Incident, Shoaled and Refracted Frequency Spectra.

4. Incident Directional Spectrum versus Frequency and Direction.

5. Refracted Directional Spectrum versus Frequency and Direction.

6. Equivalent Uni-Directional Frequency Spectrum versus Frequency.

These data files are to be utilized by the user to plot the figures as shown in the example in Appendix B. **RESHOAL** *does not* contain plotting routines.

3.4 SUBROUTINES

The 21 primary subroutines arranged in numerical order within the program are listed in Table 1. The page numbers for the subroutines listed in Table 1 correspond to the page numbers for the listing of **RESHOAL** in Appendix A. The subroutines are explained concisely with the following format [Number]-[Name]-[Description], where the [Number] refers to the numerical order in the program.

01 INPUT1 reads information from the input data file, as explained in Section 3.6.

02 DISCRE computes the frequency, time and directional domains.

03 WAVNUM calculates the wave numbers at depths h_1 and h_2, k_1 and k_2, and their ratio k_2/k_1 used in (2.1), (2.2) and (2.26).

04 GRPVEL determines the ratio of the group velocities at depths h_1 and h_2, $(Cg)_1/(Cg)_2$, used in (2.1), (2.25) and (2.26).

05 TMASPC computes the incident *TMA* frequency spectrum $S_1(f)$ at depth h_1 given by (2.11) where the peak enhancement factor γ is treated as an input parameter and the specification of the integer **IDEEP** = 1 as input results in $\Phi_K = 1$, corresponding to the JONSWAP spectrum in deep water.

FUNCTION: EJ computes the JONSWAP Spectrum given by (2.13).

06 INTGRL performs integration using Simpson's rule. It is used in **05 TMASPC, 07 DIRSPC, 09 REFDIR**, and **11 SPCPAR**.

07 DIRSPC determines the directional variables $G_o(f)$ and $s(f)$ given by (2.22) and (2.21), the directional spectrum $S_1(f, \theta_1)$ given by (2.23) and the energy distribution function $D_1(\theta_1)$ at depth h_1 defined by (2.24) with $S(f, \theta) = S_1(f, \theta_1)$.

FUNCTION: GAMMLN computes the natural log of the gamma function in (2.22) using Press *et al.* (1986).

08 SHOUNI calculates the shoaled, uni-directional frequency spectrum $S_2^u(f)$ at depth h_2 given by (2.25).

09 REFDIR calculates the refracted directional spectrum $S_2(f, \theta_2)$ given by (2.1) and (2.26), the refracted frequency spectrum $S_2(f)$ given by (2.27), and the energy distribution function $D_2(\theta_2)$ at depth h_2 defined as (2.24) with $S(f, \theta) = S_2(f, \theta_2)$. In addition, the equivalent uni-directional frequency spectrum $S_1^e(f)$ at depth h_1 given by (2.51) is computed.

10 FINDMA finds the maximum value for a given function and its location within the function's domain and is used in **08 SHOUNI** and **09 REFDIR**.

11 SPCPAR computes the spectral parameters summarized in Section 2.8 for the incident, shoaled and refracted frequency spectra denoted by $S_1(f)$, $S_2^u(f)$ and $S_2(f)$.

12 TSRIES generates the three time series $\eta(t)$ of the free surface displacements corresponding to the frequency spectra $S_1(f), S_2^u(f)$ and $S_2(f)$ using the random phase scheme and the inverse Fast Fourier Transform where the same seed value for a random number generator is used for the three time series.

External **IMSL** Subroutine: **RNSET** sets the random number generator.
External **IMSL** Subroutine: **RNUN** returns a random number array.
External **IMSL** Subroutine: **FFT2B** performs an inverse Fast Fourier Transform.

The *IMSL* subroutines **RNSET, RNUN,** and **FFT2B** are computationally efficient and are widely available throughout the U.S.A.

13 TIMPAR calculates the time series parameters summarized in Section 2.9 by the zero-upcrossing method for each time series generated in **12 TSRIES**.

14 WBREAK computes the breaker height given by (2.49) for the ranked individual waves for the three time series generated in **12 TSRIES** and analyzed in **13 TIMPAR**.

15 OFILES opens the output files described in Section 3.3.5.

16 TABINP tabulates the input and discretization parameters and lists the respective output file names.

17 TABSPC outputs the spectral parameters computed in **11 SPCPAR**.

18 TABTIM outputs the time series parameters computed in **13 TIMPAR**.

19 TABIWS tabulates the ranked individual waves and the corresponding breaker heights.

20 TABRUN tabulates the run length statistics for the zero-upcossing waves.

21 FLFIGS stores all quantities for plotting purposes.

Table 3.1: LIST OF 21 PRIMARY SUBROUTINES IN COMPUTER PROGRAM **RESHOAL.**

NO.	SUBROUTINE	PAGE NO.
01	INPUT1	46 - 48
02	DISCRE	48 - 49
03	WAVNUM	49 - 51
04	GRPVEL	51 - 52
05	TMASPC	52 - 55
06	INTGRL	55
07	DIRSPC	55 - 58
08	SHOUNI	58 - 59
09	REFDIR	59 - 61
10	FINDMA	61 - 62
11	SPCPAR	62 - 65
12	TSRIES	65 - 67
13	TIMPAR	67 - 72
14	WBREAK	72 - 73
15	OFILES	73 - 74
16	TABINP	74 - 77
17	TABSPC	77 - 79
18	TABTIM	79 - 80
19	TABIWS	80 - 82
20	TABRUN	82 - 84
21	FLFIGS	84 - 85

3.5 PARAMETERS AND VARIABLES

The **COMMON** blocks in the main program **RESHOAL** are explained in detail in this section providing the user with the necessary information to comprehend the specifics of the program and revise it as desired.

PARAMETER(NF = 2001) NF is the odd number of discrete frequencies within the frequency domain $f_{min} \leq f \leq f_{max}$ with $f_{min} = 0$. The user may increase or decrease this parameter to adjust the frequency resolution.

PARAMETER(ND = 181) ND is the odd number of discrete directions within the directional domain $-\pi/2 \leq \theta \leq \pi/2$. The user may adjust this parameter and hence the direction resolution.

PARAMETER(N = 4000) N is the integer used to dimension the number of data points in the time domain $0 \leq t < t_{max}$ and should be equal to or greater than the even number **NP** = (2 * **NF** − 2) based on (2.4). If **NF** is adjusted, N must be adjusted accordingly.

PARAMETER(NDS = 8000) NDS is the integer used to dimension the number of Fourier coefficients.

PARAMETER(NDZ = 500) NDZ is the parameter used to specify the upper limit for the number of zero upcrossing waves, **NZ**.

/CONST/ contains the following constants.

PI = π=3.141592...

G = gravitational acceleration, $g = 9.81 m/s^2$ in the SI units.

/INPUT/ contains the input parameters read from the input data file and one calculated parameter.

H(2) = 1D array containing the deeper water depth h_1 and the shallower water depth h_2.

HMO1 = spectral estimate of the significant wave height H_{mo} at the depth h_1.

TP1 = spectral peak period T_p at the depth h_1.

FP1 = spectral peak frequency at the depth h_1.

GAM = peak enhancement factor γ of the JONSWAP shape function defined by (2.16).

SMAX = maximum value s_{max} of the directional spreading parameter s at the depth h_1 given by (2.21).

ALPHA1 = predominant incident wave direction at the depth h_1 used in (2.20).

SLOPE = bottom slope m at the depth h_2 used in (2.49).

IS = seed value for the random number generator used to generate the time series of the free surface displacement as discussed in Section 2.9.

IDEEP = water depth identifier for which IDEEP = 1 specifies $\Phi_K = 1$ in (2.11), corresponding to the JONSWAP spectrum in deep water. For the *TMA* spectrum in finite depth water, set IDEEP = 0.

/OUTPUT/ contains the header information for the output files.

COMMEN1-COMMEN5 are character strings used to contain the input data file's five line header which is used to title the output files.

/DISFRQ/ contains the frequency bandwidth and domain.

DF = frequency bandwidth Δf given by (2.5).

FQ(NF) = 1D array containing the discrete frequency f_j with $j = 1, 2, 3, ..., NF$ given by (2.6).

/DISTIM/ contains the time domain and related parameters.

NP = even number of data points in the time series used in (2.4).

DT = time step Δt given by (2.8).

TIME(N) = 1D array containing the discrete time level t_n with $n = 1, 2, 3, ..., NP$ given by (2.7).

/DISDIR/ contains the directional bandwidth and domain.

DD = directional bandwidth $\Delta\theta$ specified by (2.9).

THETA(ND) = 1D array containing the discrete direction θ_i with $i = 1, 2, 3, ..., ND$ given by (2.10).

/MINMAX/ contains the minimum and maximum frequencies and periods.

FMIN = minimum frequency f_{min} which is set as $f_{min} = 0$.

FMAX = maximum frequency f_{max} specified in Section 2.2.

TMIN = minimum time level t_{min} which is set as $t_{min} = 0$.

TMAX = maximum time level t_{max} which is selected as $t_{max} = 200T_p$.

/WNUMBR/ contains the wave number and group velocity parameters.

WN(2,NF) = 2D array containing the wave numbers k_1 and k_2 computed using (2.3) for each discrete frequency f_j.

WN21(NF) = 1D array containing the ratio k_2/k_1 for each discrete frequency f_j.

CG12(NF) = 1D array containing the ratio $(Cg)_1/(Cg)_2$ of the group velocities at the depths h_1 and h_2 for each discrete frequency f_j.

/FQSPEC/ contains the incident, shoaled, refracted, and equivalent uni-directional frequency spectra.

STMA(NF) = 1D array containing the incident frequency spectrum $S_1(f_j)$ given by (2.11).

SUNI(NF) = 1D array containing the shoaled frequency spectrum $S_2^u(f_j)$ given by (2.25).

SDIR(NF) = 1D array containing the refracted frequency spectrum $S_2(f_j)$ given by (2.27).

SEQU(NF) = 1D array containing the equivalent uni-directional frequency spectrum $S_1^e(f)$ given by (2.51).

/MITSU/ contains the parameters of the directional spreading function $G_1(f,\theta)$ given by (2.20).

S(NF) = 1D array containing the directional spreading parameter $s(f_j)$ given by (2.21).

G0(NF) = 1D array containing the directional spreading parameter $G_o(f_j)$ given by (2.22).

/DIREC1/ contains the directional spectrum and energy distribution function at the deeper depth h_1.

S1(NF,ND) = 2D array containing the incident directional spectrum $S_1(f_j, \theta_i)$ computed by (2.23).

D1(ND) = 1D array containing the incident directional energy distribution function $D_1(\theta_i)$ defined as (2.24) using $S_1(f, \theta_1)$.

/DIREC2/ contains the directional spectrum and energy distribution function at the shallower depth h_2.

S2(NF,ND) = 2D array containing the refracted directional spectrum $S_2(f_j, \theta_i)$ given by (2.1) and (2.26).

D2(ND) = 1D array containing the refracted directional energy distribution function $D_2(\theta_i)$ defined as (2.24) using $S_2(f, \theta_2)$.

/PEAKS/ contains the peak frequency, period and predominant wave direction at the shallower depth h_2.

FPUNI = peak frequency f_p of the shoaled frequency spectrum where $S_2^u(f_j)$ is the maximum.

TPUNI = peak period T_p of the shoaled frequency spectrum which is equal to 1/**FPUNI**.

FPDIR = peak frequency f_p of the refracted frequency spectrum where $S_2(f_j)$ is the maximum.

TPDIR = peak period T_p of the refracted frequency spectrum which is equal to 1/**FPDIR**.

ALPHA2 = predominant wave direction of the refracted directional spectrum where $D_2(\theta_i)$ is the maximum.

/SPCTRM/ contains the three frequency spectra for convenience of programming.

SP(3,NF) = 2D array containing the three frequency spectra such that **SP(1,NF)** = **STMA(NF)**, **SP(2,NF)** = **SUNI(NF)** and **SP(3,NF)** = **SDIR(NF)**.

/SPECP/ contains the frequency spectral parameters.

SPECP(3,12) = 2D array containing the spectral parameters for the three frequency spectra as follows:

EP = **SPECP(*,1)** = spectral width parameter ϵ given by (2.29).

VU = **SPECP(*,2)** = spectral width parameter ν given by (2.30).

QP = **SPECP(*,3)** = spectral peakedness parameter Q_p given by (2.31).

ER = **SPECP(*,4)** = standard deviation of the free surface oscillation, η_{rms} given by (2.32).

HR = **SPECP(*,5)** = spectral estimate of the root-mean-square wave height H_{rms} given by (2.33).

HM = **SPECP(*,6)** = spectral estimate of the significant wave height H_{mo} given by (2.34).

T1 = **SPECP(*,7)** = spectral estimate of the mean period T_{01} given by (2.35).

T2 = **SPECP(*,8)** = spectral estimate of the mean period T_{02} given by (2.36).

TP* = spectral peak period for the three spectra denoted by the following:

TP1 = **SPECP(1,9)** = peak period at depth h_1.

TPUNI = **SPECP(2,9)** = peak period of normally-incident frequency spectrum at depth h_2.

TPDIR = **SPECP(3,9)** = peak period of refracted frequency spectrum at depth h_2.

FP* = spectral peak frequency for the three spectra denoted by the following:

FP1 = **SPECP(1,10)** = peak frequency at depth h_1.

FPUNI = **SPECP(2,10)** = peak frequency of normally-incident frequency spectrum at depth h_2.

FPDIR = **SPECP(3,10)** = peak frequency of refracted frequency spectrum at depth h_2.

ALPHA* = predominant incident wave direction denoted by the following:

ALPHA1 = **SPECP(1,11)** = predominant incident wave direction at depth h_1.

ALPHA2 = **SPECP(2,11)** = predominant incident wave direction for normally incident frequency spectrum at depth h_2 which is equal to zero.

ALPHA2 = **SPECP(3,11)** = predominant incident wave direction at depth h_2.

KP = **SPECP(*,12)** = spectral correlated parameter given by (2.37).

/SERIES/ contains the three time series generated numerically for the three frequency spectra.

TS(3,N) = 2D array containing the three time series of the free surface displacement $\eta(t_n)$ such that **TS(1,N)** = $\eta_1(t_n)$ for $S_1(f_j)$, **TS(2,N)** = $\eta_2^u(t_n)$ for $S_2^u(f_j)$, and **TS(3,N)** = $\eta_2(t_n)$ for $S_2(f_j)$.

/UPCROS/ contains the ranked time series parameters.

NZ(3) = 1D array containing the number N_o of zero upcrossing waves for the three time series in sequence of $\eta_1(t_n), \eta_2^u(t_n)$ and $\eta_2(t_n)$.

HRK(3,NDZ) = 2D array containing the ranked wave heights H_r with $r = 1, 2, 3, ..., No$ for the three time series.

TRK(3,NDZ) = 2D array containing the wave periods T_r associated with the ranked wave heights for the three time series.

NK(3) = 1D array containing the number NK of runs for the three time series.

LRN(3,NDZ) = 2D array containing the run length $LRN(j)$ with $j = 1, 2, 3, ..., NK$ of wave heights exceeding the significant wave height H_s for the three time series.

/TIMEPR/ contains the time series parameters.

TIMEP(3,12) = 2D array containing the time series parameters for the three time series as follows:

SD = **TIMEP(*,1)** = mean water level $\overline{\eta}$ given by (2.38).

ER = **TIMEP(*,2)** = standard deviation of the free surface displacement η_{rms} given by (2.39).

NZ = **TIMEP(*,3)** = number of zero upcrossings N_0 given by (2.40).

HB = **TIMEP(*,4)** = average wave height $\overline{H}$ given by (2.41).

TB = **TIMEP(*,5)** = average wave period $\overline{T}$ given by (2.42).

HV = **TIMEP(*,6)** = root-mean-square wave height H_{rms} given by (2.43).

HS = **TIMEP(*,7)** = significant wave height, *i.e.*, the average of the one-third heighest waves, H_s, given by (2.44).

T3 = **TIMEP(*,8)** = significant wave period, *i.e.*, the average period of the one-third highest waves, T_s, given by (2.45).

HT = **TIMEP(*,9)** = average height of the one-tenth highest waves, H_{10}, given by (2.46).

TT = **TIMEP(*,10)** = average period of the one-tenth highest waves, T_{10}, given by (2.47).

NK = **TIMEP(*,11)** = number of runs exceeding the significant wave height, H_s.

$\overline{J}$ = **TIMEP(*,12)** = mean run length given by (2.48).

/WAVEBK/ contains the individual wave breaking statistics.

HBREAK(3,NDZ) = 2D array containing the breaker heights H_b given by (2.49) for each ranked wave for the shoaled time series $\eta_2^u(t_n)$ and the refracted time series $\eta_2(t_n)$.

IBREAK(3,NDZ) = 2D array containing the breaker indicator of each ranked wave for the shoaled and refracted time series. **IBREAK** = 1 for $H_r \geq H_b$, that is, breaking of the r-th ranked wave. **IBREAK** $= 0$ for $H_r < H_b$, that is, no breaking of the r-th ranked wave.

3.6 FORMATTING AND READING THE INPUT DATA FILE

The input data file is read by Subroutine **01 INPUT1**. This section describes the input format so the user will be able to prepare the input data file easily.

3.6.1 FILE NAME

RESHOAL allows the user to name the input data file **FILENM, UNIT = 10**. The file name is limited to thirteen characters and is read in as follows:

```
      CHARACTER*13 FILENM
        •
        •
        •
C REQUEST INPUT FILE NAME
      WRITE(*,*) 'ENTER INPUT FILE NAME AND EXTENSION'
      READ(*,10) FILENM
        •
        •
        •
10    FORMAT(A13)
```

3.6.2 HEADER

The first five lines of the input file shall contain header information **COMMEN1, COMMEN2, COMMEN3, COMMEN4** and **COMMEN5**. This header is then written to the output files for titling purposes. The header lines are limited to thirty characters each and are read in as follows:

```
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,
                   COMMEN4,COMMEN5
        •
        •
        •
C                        READ HEADER
      READ(10,20) COMMEN1
      READ(10,20) COMMEN2
      READ(10,20) COMMEN3
      READ(10,20) COMMEN4
      READ(10,20) COMMEN5
        •
        •
        •
20    FORMAT(A30)
```

3.6.3 INPUT DATA

Following the header in the data file, the input parameters shall be specified in the following order:

- **H(M)** = water depths denoted by **H(1)** = h_1 and **H(2)** = h_2
- **HMO1** = spectral estimate of the significant wave height H_{mo} at the depth h_1
- **TP1** = spectral peak period T_p at the depth h_1
- **GAM** = peak enhancement factor γ of the JONSWAP shape function
- **IDEEP** = water depth identifier

- **SMAX** = maximum value s_{max} of the directional spreading parameter s at the depth h_1
- **ALPHA1** = predominant incident wave direction at the depth h_1
- **SLOPE** = bottom slope m at the depth h_2
- **IS** = seed value for the random number generator.

RESHOAL reads in these parameters as follows:

```
READ(10,*) (H(M), M=1,2)

READ(10,*) HMO1,TP1

READ(10,*) GAM,IDEEP

READ(10,*) SMAX,ALPHA1

READ(10,*) SLOPE

READ(10,*) IS
```

3.7 OUTPUT DATA FILES

Subroutine **15 OFILES** opens all the output files for storing and tabulating data and are listed below. Note, each output data file contains the header described in Section 3.6.2.

INPUT is an output data file listing the input parameters and preset variables described in Sections 2.2 and 3.6.3 and placed in the following order:

- **H(1)** = the deeper depth h_1 (m)
- **H(2)** = the shallower depth h_2 (m)

- **HMO1** = spectral estimate of the significant wave height H_{mo} at the depth h_1 (m)
- **TP1** = spectral peak period T_p at the depth h_1 (s)
- **GAM** = peak enhancement factor γ of the JONSWAP shape function
- **IDEEP** = water depth identifier
- **SMAX** = maximum value s_{max} of the directional spreading parameter s at the depth h_1
- **ALPHA1** = predominant incident wave direction at the depth h_1 (deg)
- **SLOPE** = bottom slope m at the depth h_2
- **IS** = seed value for the random number generator
- **NF** = number of discrete frequencies
- **ND** = number of discrete directions
- **FMIN** = lower bound of the frequency domain set equal to zero (Hz)
- **FMAX** = upper bound of the frequency domain (Hz)
- **TMIN** = lower bound of the directional domain set equal to $-90°$
- **TMAX** = upper bound of the directional domain set equal to $90°$.

FQ is an output file containing the frequency domain **FQ(J)** where **J = 1,2,3,...,NF** calculated in Section 2.2 for plotting purposes.

ANG is an output file containing the directional domain **THETA(I)** where **I = 1,2,3,..., ND** calculated in Section 2.2 for plotting purposes.

TIME is an output file containing the time domain **TIME(K)** where **K = 1,2,3,...,NP** calculated in Section 2.2 for plotting purposes.

SPECP is an output data file listing the spectral parameters described in Section 2.8 for the three frequency spectra and specified below:

- **SPECP(*,1)** = spectral width parameter ϵ
- **SPECP(*,2)** = spectral width parameter ν
- **SPECP(*,3)** = spectral peakedness parameter Q_p
- **SPECP(*,4)** = standard deviation of the free surface oscillation, η_{rms}
- **SPECP(*,5)** = spectral estimate of the root-mean-square wave height H_{rms}
- **SPECP(*,6)** = spectral estimate of the significant wave height H_{mo}
- **SPECP(*,7)** = spectral estimate of the mean period T_{01}
- **SPECP(*,8)** = spectral estimate of the mean period T_{02}
- **SPECP(*,9)** = peak period of the frequency spectrum
- **SPECP(*,10)** = peak frequency of the frequency spectrum
- **SPECP(*,11)** = predominant incident wave direction of the frequency spectrum
- **SPECP(*,12)** = spectral correlated parameter κ

TIMEP is an output data file listing the time series parameters described in Section 2.9 for the three time series and specified below:

- **TIMEP(*,1)** = mean water level $\overline{\eta}$
- **TIMEP(*,2)** = standard deviation of the free surface displacement, η_{rms}
- **TIMEP(*,3)** = number of zero upcrossings, N_0
- **TIMEP(*,4)** = average wave height $\overline{H}$

- **TIMEP(*,5)** = average wave period $\overline{T}$
- **TIMEP(*,6)** = root-mean-square wave height H_{rms}
- **TIMEP(*,7)** = significant wave height, *i.e.*, average of one-third heighest waves, H_s
- **TIMEP(*,8)** = significant wave period, *i.e.*, average period of one-third highest waves, T_s
- **TIMEP(*,9)** = average height of the one-tenth highest waves, H_{10}
- **TIMEP(*,10)** = average period of the one-tenth highest waves, T_{10}
- **TIMEP(*,11)** = number of runs exceeding the significant wave height H_s
- **TIMEP(*,12)** = mean run length

UNIBRK is an output data file listing the ranked waves and breaker heights for the incident versus shoaled uni-directional frequency spectra described in Sections 2.9 and 2.10 and specified below:

- **TRK(1,NZ)** = wave periods T_r associated with the ranked wave heights for the incident frequency spectrum
- **HRK(1,NZ)** = ranked wave heights H_r for the incident frequency spectrum
- **TRK(2,NZ)** = wave periods T_r associated with the ranked wave heights for the shoaled uni-directional frequency spectrum
- **HRK(2,NZ)** = ranked wave heights H_r for the shoaled uni-directional frequency spectrum
- **HBREAK(2,NZ)** = breaker heights for the shoaled uni-directional frequency spectrum

- **IBREAK(2,NZ)** = breaker indicator for the shoaled uni-directional frequency spectrum

DIRBRK is an output data file listing the ranked waves and breaker heights for the incident versus refracted directional frequency spectra described in Sections 2.9 and 2.10. The format for **DIRBRK** is the same as for **UNIBRK** except that the shoaled uni-directional frequency spectrum is replaced by the refracted directional frequency spectrum.

RUNLTH is an output data file listing the run length statistics described in Section 2.9 for the three time series and specified below:

- **LRN(*,NK)** = run length of wave heights exceeding H_s
- **TIMEP(*,12)** = mean run length

STMA is an output file containing the *TMA* frequency spectrum **STMA(J)** where **J** = **1,2,3,...,NF** at depth h_1 described in Section 2.3 for plotting purposes.

SUNI is an output file containing the shoaled uni-directional frequency spectrum **SUNI(J)** where **J** = **1,2,3,...,NF** at depth h_2 described in Section 2.6 for plotting purposes.

SDIR is an output file containing the refracted frequency spectrum **SDIR(J)** where **J** = **1,2,3,...,NF** at depth h_2 described in Section 2.7 for plotting purposes.

SEQU is an output file containing the equivalent uni-directional frequency spectrum **SEQU(J)** where **J** = **1,2,3,...,NF** at depth h_1 described in Section 2.11 for plotting purposes.

D1 is an output file containing the directional energy distribution function **D1(I)** where **I** = **1,2,3,...,ND** at depth h_1 described in Section 2.5 for plotting purposes.

D2 is an output file containing the directional energy distribution function **D2(I)** where **I = 1,2,3,...,ND** at depth h_2 described in Section 2.5 for plotting purposes.

DIRSP1 is an output file containing the directional spectrum **S1(J,I)** where **J = 1,2,3,...,NF** and **I = 1,2,3,...,ND** at depth h_1 described in Section 2.4 for plotting purposes.

DIRSP2 is an output file containing the directional spectrum **S2(J,I)** where **J = 1,2,3,...,NF** and **I = 1,2,3,...,ND** at depth h_2 described in Sections 2.1 and 2.7 for plotting purposes.

TS1 is an output file containing the time series for the incident frequency spectrum, **TS(1,K)**, where **K = 1,2,3,...,NP** at depth h_1 described in Section 2.9 for plotting purposes.

TS2 is an output file containing the time series for the shoaled uni-directional frequency spectrum, **TS(2,K)**, where **K = 1,2,3,...,NP** at depth h_2 described in Section 2.9 for plotting purposes.

TS3 is an output file containing the time series for the refracted frequency spectrum, **TS(3,K)**, where **K = 1,2,3,...,NP** at depth h_2 described in Section 2.9 for plotting purposes.

3.8 USER MODIFICATONS

Subroutine **15 OFILES** may be revised by the user to rename any or all of the output file names. The extension **OUT** for data files and **DATA** for plotting files was chosen specifically for the authors' computer system and should be revised as necessary. Also, Subroutines 16 through 21 may be amended to reformat the output files.

The number of frequencies used throughout **RESHOAL** is specified in the main program using the **PARAMETER** statement, **PARAMETER(NF= 2001)**. To increase or decrease the number of frequencies, the user must modify this **PARAMETER** statement appearing in the main program and Subroutines 02 through 05, 07 through 09, 11, 12, 16 and 21. Accordingly, the number of data points, **NP**, equal to (2∗**NF**−2), will change and the user must adjust the **PARAMETER** statement, **PARAMETER(N = 4000)**, appearing in the main program and Subroutines 02, 12, 13, 16 and 21 in suit. Also, the parameter **NDS** equal to (2∗**NP**) used in the FFT routines will have to increase or decrease as necessary in the main program and subroutines 12 and 13.

Similarly, the user may increase or decrease the directional resolution, **ND**. **RESHOAL** contains a 1° angular step corresponding to **ND** equal to 181. The **PARAMETER** statement, **PARAMETER(ND = 181)**, appearing in the main program and Subroutines 02, 07, 09, 11, 16 and 21, should be revised as necessary.

The dimensioning for the arrays containing the number of zero upcrossing waves may have to be adjusted depending upon the length of the time domain set to be 200**TP1**. A dimension size of 500 should be sufficient. The **PARAMETER** statement, **PARAMETER(NDZ = 500)** appears in the main program and in subroutines 13, 14, 19 and 20.

Subroutine **02 DISCRE** may be modified to alter the upper and lower bounds of the discretized domains. The minimum and maximum frequencies are preset to 0 and 10/**TP1**, respectively. The directions $-\pi/2$ and $\pi/2$ parallel to the straight shoreline establish the physical lower and upper bounds on the directional domain. The user may revise these limits if necessary.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

The computer program **RESHOAL** computes the directional random wave spectrum in specified shallower water depth for given incident directional random wave spectrum in deeper water depth using linear finite-depth theory for straight shorelines with parallel bottom contours. The incident directional random wave spectrum is simply assumed to be given by the product of the *TMA* frequency spectrum and the Mitsuyasu-type directional spreading function since incident directional random wave data may not be available for practical applications. Although the linear finite-depth theory is well established, the user-friendly computer program **RESHOAL** with the minimum input and various output will allow more routine applications of this theory.

RESHOAL is limited to straight shorelines with parallel bottom contours and can not be applied to complex bathymetry. The linear finite-depth theory is limited to the region outside the surf zone in which cumulative effects of wind and bottom friction are negligible. The linear theory has been shown to be reasonably accurate in predicting the gross wave characteristics such as the spectral estimate of the significant wave height. The linear theory may not predict the details of the wave spectra since it does not account for the generation of higher and lower harmonics due to nonlinear wave-wave interactions.

RESHOAL may be sufficient for determining the representative wave height and period used for the current design procedures of coastal structures, although other wave characteristics such as the spectral shape and wave grouping are being investigated to improve the specification of design waves.

The applications of **RESHOAL** are given in Appendices B and C in relation to field data and generation of equivalent uni-directional frequency spectra in a two-dimensional wave flume. **RESHOAL** may be used to estimate the incident random waves required as input to other numerical models developed for the design of coastal structures. The use of the equivalent uni-directional frequency spectra in the two-dimensional model tests has been examined by Poff and Kobayashi (1993).

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Appendix A

LISTING OF COMPUTER PROGRAM RESHOAL

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                        C
C     RESHOAL:  PROGRAM RESHOAL COMPUTES THE SHOALING AND                C
C         REFRACTION OF DIRECTIONAL RANDOM WAVES PROPAGATING ONTO        C
C          A STRAIGHT SHORELINE WITH PARALLEL BOTTOM CONTOURS            C
C                                                                        C
C           WRITTEN BY MICHAEL POFF AND NOBUHISA KOBAYASHI               C
C     CENTER FOR APPLIED COASTAL RESEARCH, UNIVERSITY OF DELAWARE        C
C                               JULY, 1993                               C
C                                                                        C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C     PARAMETERS
C     -------------------------------------------------------------------
C     NAME               DESCRIPTION
C     -------------------------------------------------------------------
C     PARAMETER(NF=2001) NF is the number of frequencies within the fre-
C     quency domain.
C     PARAMETER(ND=181) ND is the number of directions within the direc-
C     tional domain.
C     PARAMETER(N=4000) N is the integer used to dimension the time
C     domain.
C     PARAMETER(NDS=8000) NDS is the integer used to dimension the
C     number of Fourier Coefficients.
C     PARAMETER(NDZ=500) NDZ is the upper limit of the number of zero-
C     upcrossing waves in the time domain.
C
C     COMMONs
C     -------------------------------------------------------------------
C     NAME    CONTENTS
C     -------------------------------------------------------------------
C     /CONST/  contains constants.
```

```
C      /INPUT/  contains input parameters read from the input data file
C               and one calculated parameter.
C      /OUTPUT/ contains header information for output files.
C      /DISFRQ/ contains the frequency domain and related variables.
C      /DISTIM/ contains the time domain and related variables.
C      /DISDIR/ contains the directional domain and related variables.
C      /MINMAX/ contains the minimum and maximum frequencies and time
C               levels.
C      /WNUMBR/ contains the wave number and group velocity variables.
C      /FQSPEC/ contains the incident, shoaled, refracted, and equivalent
C               uni-directional frequency spectra.
C      /MITSU/  contains the directional spreading parameters.
C      /DIREC1/ contains the directional spectrum and energy distribution
C               function at deeper depth one.
C      /DIREC2/ contains the directional spectrum and energy distribution
C               function at shallower depth two.
C      /PEAKS/  contains the peak frequencies, periods and predominant
C               wave direction at shallower depth two.
C      /SPCTRM/ contains all three frequency spectra for use in Sub-
C               routines 11 SPCPAR and 12 TSRIES.
C      /SPECP/  contains the frequency spectral parameters.
C      /SERIES/ contains the three time series generated for the three
C               frequency spectra.
C      /UPCROS/ contains the ranked wave parameters and wave group
C               statistics.
C      /TIMEPR/ contains the time series parameters for the three time
C               series.
C      /WAVEBK/ contains the breaker height for the ranked waves.

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      PARAMETER (N=4000)
      PARAMETER (NDS=8000)
      PARAMETER (NDZ=500)
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5

C PROVIDE IMSL WORKSPACE
      REAL RWKSP(32056)
      COMMON/WORKSP/RWKSP

      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
```

```
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISTIM/NP,DT,TIME(N)
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/MINMAX/FMIN,FMAX,TMIN,TMAX
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/MITSU/S(NF),GO(NF)
      COMMON/DIREC1/S1(NF,ND),D1(ND)
      COMMON/DIREC2/S2(NF,ND),D2(ND)
      COMMON/PEAKS/FPUNI,TPUNI,FPDIR,TPDIR,ALPHA2
      COMMON/SPCTRM/SP(3,NF)
      COMMON/SPECP/SPECP(3,12)
      COMMON/SERIES/TS(3,N)
      COMMON/UPCROS/NZ(3),HRK(3,NDZ),TRK(3,NDZ),NK(3),LRN(3,NDZ)
      COMMON/TIMEPR/TIMEP(3,12)
      COMMON/WAVEBK/HBREAK(3,NDZ),IBREAK(3,NDZ)

C     CALL TO IMSL WORKSPACE
      CALL IWKIN(32056)

C CONSTANTS
C                         PI=3.14159...
      PI=4.*ATAN(1.)
C                         G=9.81 (m/s^2)=GRAVITATIONAL ACCELERATION
      G=9.81

C SPECIFY INPUT VALUES USING 01 INPUT1
      CALL INPUT1

C CALCULATE FREQUENCY, TIME AND DIRECTIONAL DOMAINS USING 02 DISCRE
      CALL DISCRE

C CALCULATE RATIO OF WAVE NUMBERS AT DEPTHS 1 & 2 USING 03 WAVNUM
      CALL WAVNUM

C CALCULATE RATIO OF GROUP VELOCITIES USING 04 GRPVEL
      CALL GRPVEL

C CALCULATE FREQUENCY SPECTRUM AT DEPTH 1 USING 05 TMASPC
      CALL TMASPC

C CALCULATE DIRECTIONAL SPREADING PARAMETERS, SPECTRUM AND
C ENERGY DISTRIBUTION FUNCTION AT DEPTH 1 USING 07 DIRSPC
      CALL DIRSPC
```

```
C CALCULATE SHOALED UNIDIRECTIONAL FREQUENCY SPECTRUM AT DEPTH 2
C USING 08 SHOUNI
      CALL SHOUNI

C CALCULATE DIRECTIONAL SPECTRUM AT DEPTH 2 USING 09 REFDIR
      CALL REFDIR

C CALCULATE SPECTRAL PARAMETERS USING 11 SPCPAR
      CALL SPCPAR

C CALCULATE TIME SERIES USING 12 TSRIES
      CALL TSRIES

C CALCULATE TIME SERIES PARAMETERS USING 13 TIMPAR
      CALL TIMPAR

C CALCULATE BREAKING HEIGHTS AND INDICATORS USING 14 WBREAK
      CALL WBREAK

C OUTPUT USING SUBROUTINES 15-21
      CALL OFILES
      CALL TABINP
      CALL TABSPC
      CALL TABTIM
      CALL TABIWS
      CALL TABRUN
      CALL FLFIGS

      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                          SUBROUTINES & FUNCTIONS                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 01  CCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                        C
C  INPUT1                                                                C
C                                                                        C
C  READS INPUT PARAMETERS FOR PROGRAM RESHOAL FROM USER SPECIFIED        C
C  INPUT DATA FILE (UNIT=10)                                             C
C                                                                        C
C        IN/OUT:                                                         C
C     H(M).........WATER DEPTHS 1 & 2 (M=1,2) (M)                        C
```

```
C     HM01.........SPECTRAL ESTIMATE OF SIGNIFICANT WAVE HEIGHT AT     C
C                  DEPTH 1 (M)                                         C
C     TP1..........PEAK PERIOD AT DEPTH 1 (S)                          C
C     GAM..........PEAK ENHANCEMENT FACTOR OF JONSWAP SPECTRUM         C
C     IDEEP........WATER DEPTH IDENTIFIER: SET IDEEP=1 FOR DEEP WATER  C
C                  SPECTRUM                                            C
C     SMAX.........MAX. VALUE OF DIRECTIONAL SPREADING PARAMETER, S,   C
C                  AT DEPTH 1                                          C
C     ALPHA1.......PREDOMINANT INCIDENT WAVE DIRECTION AT DEPTH 1 (RAD)C
C     SLOPE........BOTTOM SLOPE AT DEPTH 2                             C
C     IS...........SEED VALUE FOR RANDOM NO. GENERATOR                 C
C                                                                      C
C        OUT:                                                          C
C     FP1...........PEAK FREQUENCY AT DEPTH 1 (HZ)                     C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE INPUT1

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      CHARACTER*13 FILENM
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5

C REQUEST INPUT FILE NAME (UNIT=10)
      WRITE(*,*) 'ENTER INPUT FILE NAME AND EXTENSION'
      READ(*,10) FILENM

C OPEN INPUT DATA FILE
      OPEN(UNIT=10,FILE=FILENM)
C                                READ HEADER
      READ(10,20) COMMEN1
      READ(10,20) COMMEN2
      READ(10,20) COMMEN3
      READ(10,20) COMMEN4
      READ(10,20) COMMEN5

C                                READ INPUT PARAMETERS
C                                WATER DEPTHS 1 & 2
      READ(10,*) (H(M),M=1,2)
C                                SIGN WAVE HT & PEAK PERIOD AT DEPTH 1
      READ(10,*) HM01,TP1
C                                SPECTRAL PARAMETER GAMMA & WATER DEPTH
```

```
C                                 IDENTIFIER IDEEP
      READ(10,*) GAM,IDEEP
C                                 DIRECTIONAL PARAMETERS SMAX & ALPHA1
      READ(10,*) SMAX,ALPHA1
C                                 BOTTOM SLOPE
      READ(10,*) SLOPE
C                                 RANDOM NO. SEED VALUE
      READ(10,*) IS

C CALCULATE PEAK FREQUENCY AT DEPTH 1
      FP1=1./TP1

 10   FORMAT(A13)
 20   FORMAT(A30)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 02  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  DISCRE                                                              C
C                                                                      C
C  COMPUTES FREQUENCY, TIME AND DIRECTIONAL DOMAINS                    C
C                                                                      C
C        IN:                                                           C
C     TP1..........PEAK PERIOD AT DEPTH 1 (SEC)                        C
C                                                                      C
C        OUT:                                                          C
C     NF...........NO. OF DISCRETE FREQUENCIES                         C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                  C
C     FQ(NF).......FREQUENCY DOMAIN (HZ)                               C
C     NP...........EVEN NO. OF DATA POINTS IN TIME SERIES              C
C     DT...........TIME STEP (DELTA T)                                 C
C     TIME(N)......TIME DOMAIN (S)                                     C
C     ND...........NO. OF DISCRETE DIRECTIONS                          C
C     DD...........DIRECTIONAL BANDWIDTH (RADS)                        C
C     THETA(ND)....DIRECTIONAL DOMAIN (RADS)                           C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE DISCRE

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
C USER MAY INCREASE/DECREASE NUMBER OF FREQUENCIES/DIRECTIONS AS DESIRED
```

```
C NOTE:  PARAMETERS MUST BE ADJUSTED ACCORDINGLY
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      PARAMETER (N=4000)
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISTIM/NP,DT,TIME(N)
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/MINMAX/FMIN,FMAX,TMIN,TMAX

C DISCRETIZE FREQUENCY DOMAIN
      FMIN= 0.0
      FMAX= 10./TP1
      DF=(FMAX-FMIN)/(FLOAT(NF)-1.)

      DO 100 J=1,NF
       FQ(J)=FMIN+(FLOAT(J)-1.)*DF
 100  CONTINUE

C CALCULATE TIME DOMAIN FOR SUBSEQUENT TIME SERIES COMPUTATIONS
      NP=2*NF-2
      DT=1./(2.*FMAX)
      TIMEMIN=0.

      DO 200 K=1,NP
       TIME(K)=TIMEMIN+(FLOAT(K)-1.)*DT
 200  CONTINUE

C DISCRETIZE DIRECTIONAL DOMAIN AT DEPTH 2
C                               THETA RANGES FROM -PI/2 TO PI/2
      TMAX=PI/2.
      TMIN=-PI/2.
C                               FOR 1 DEGREE INCREMENT
      DD=(TMAX-TMIN)/(FLOAT(ND)-1.)

      DO 300 I=1,ND
       THETA(I)=TMIN+(FLOAT(I)-1.)*DD
 300  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 03  CCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
C                                                                         C
C  WAVNUM                                                                 C
C                                                                         C
C  COMPUTES WAVE NUMBERS AT DEPTHS 1 & 2 AND THEIR RATIO                  C
C  THIS SUBROUTINE IS AN IMPROVED VERSION OF THE SUBROUTINE WAVNUM IN     C
C  COX ET AL. (1991) TO COMPUTE A WAVE NUMBER                             C
C                                                                         C
C        IN:                                                              C
C     FQ(NF).......FREQUENCY (HZ)                                         C
C     H(M).........WATER DEPTHS 1 & 2 (M)                                 C
C                                                                         C
C        OUT:                                                             C
C     WN(M,NF).....WAVE NUMBER FOR SPECIFIED FQ(NF) AT DEPTHS             C
C                  1 & 2 (1/M)                                            C
C     WN21(NF).....RATIO OF WAVE NUMBERS AT DEPTHS 2 & 1                  C
C                                                                         C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE WAVNUM

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NF=2001)
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)

      DO 100 M=1,2
       DO 200 J=1,NF
        SIG=2.*PI*FQ(J)
        R=SIG**2*H(M)/G
        IF(R.GE.10.)THEN
         WN(M,J)=R/H(M)
         GO TO 200
        ENDIF
        IF(R.LE.1.E-8)THEN
         WN(M,J)=SQRT(R)/H(M)
         GO TO 200
        ENDIF
        IF(R.GE.1.)THEN
         X=R
        ELSE
         X=SQRT(R)
        ENDIF
```

```
 300     COTH=1./TANH(X)
         XP=X-((X-R*COTH)/(1.+R*(COTH**2-1.)))
         D=ABS(1-XP/X)
         X=XP
         IF(D.GT.1.E-6) GO TO 300
         WN(M,J)=X/H(M)
 200    CONTINUE
 100   CONTINUE

C CALCULATE RATIO OF WAVE NUMBERS
      WN21(1)=SQRT(H(1)/H(2))
      DO 500 J=2,NF
       WN21(J)=WN(2,J)/WN(1,J)
 500   CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 04  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  GRPVEL                                                              C
C                                                                      C
C  COMPUTES RATIO OF GROUP VELOCITIES                                  C
C                                                                      C
C        IN:                                                           C
C     NF...........NO. OF DISCRETE FREQUENCIES                         C
C     H(M).........WATER DEPTHS 1 & 2 (M)                              C
C     WN(M,NF).....WAVE NUMBER FOR SPECIFIED FREQUENCY AT              C
C                  DEPTHS 1 & 2 (1/M)                                  C
C     WN21(NF).....RATIO OF WAVE NUMBERS AT DEPTHS 2 & 1               C
C                                                                      C
C        OUT:                                                          C
C     CG12(NF).....RATIO OF GROUP VELOCITIES AT DEPTHS 1 & 2           C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE GRPVEL

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NF=2001)
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)

C CALCULATE RATIO OF GROUP VELOCITIES
```

```
      CG12(1)=WN21(1)
      DO 100 J=2,NF
       X1=2.*H(1)*WN(1,J)
       X2=2.*H(2)*WN(2,J)
C LIMIT FOR SINH(ARG), ARG<150
       IF(X1.GT.150.)THEN
        F1=0.0
       ELSE
        F1= X1/SINH(X1)
       ENDIF
       IF(X2.GT.150.)THEN
        F2=0.0
       ELSE
        F2= X2/SINH(X2)
       ENDIF
       CG12(J)=WN21(J)*((1.+F1)/(1.+F2))
 100  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 05  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  TMASPC                                                              C
C                                                                      C
C  SUBROUTINE TMASPC IN COX ET AL. (1991) IS MODIFIED HEREIN           C
C                                                                      C
C  COMPUTES FREQUENCY SPECTRUM FOR WIND WAVES IN FINITE OR DEEP        C
C  WATER DEPTH                                                         C
C                                                                      C
C        IN:                                                           C
C     IDEEP........WATER DEPTH IDENTIFIER: SET IDEEP=1 FOR DEEP WATER  C
C                  SPECTRUM                                            C
C     NF...........NO. OF DISCRETE FREQUENCIES                         C
C     WN(1,NF).....WAVE NUMBER FOR SPECIFIED FQ(NF) AT DEPTH 1 (1/M)   C
C     H(1).........WATER DEPTH 1 (M)                                   C
C     FQ(NF).......FREQUENCY DOMAIN (HZ)                               C
C     FP1..........PEAK FREQUENCY AT DEPTH 1 (HZ)                      C
C     HM01.........SPECTRAL ESTIMATE OF SIGNIFICANT WAVE HEIGHT AT     C
C                  DEPTH 1 (M)                                         C
C     GAM..........PEAK ENHANCEMENT FACTOR OF JONSWAP SPECTRUM         C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                  C
C                                                                      C
C        OUT:                                                          C
```

```
C     STMA(NF).....FREQUENCY SPECTRUM AT DEPTH 1 (M*M*S)                    C
C                                                                           C
C     INTERNAL FUNCTION SUBROUTINE:  EJ(FQ,FP)                              C
C                                                                           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TMASPC

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NF=2001)
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/CONST/PI,G
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)

C SET AP=1 AND COMPUTE ITS VALUE LATER FOR GIVEN HM01
      AP=1.

C SET FREQUENCY SPECTRUM=0 FOR J=1, THAT IS, ZERO FREQUENCY
      STMA(1)=0.

C SET PHIK = 1.0 IN DEEP WATER (IDEEP=1) AND COMPUTE JONSWAP SPECTRUM
      IF(IDEEP.EQ.1)THEN
       PHIK=1.
       DO 50 J=2,NF
        STMA(J)=AP*EJ(FQ(J),FP1)*PHIK
 50    CONTINUE
      ELSE
C OTHERWISE COMPUTE PHIK AND TMA SPECTRUM FOR FINITE DEPTH
       DO 100 J=2,NF
        AKH=WN(1,J)*H(1)
        AKH2=AKH*2.
C LIMIT FOR SINH(ARG), ARG<150
        IF(AKH2.GT.150.)THEN
         PHIK=1.
        ELSE
         PHIK=(TANH(AKH))**2/(1.+AKH2/SINH(AKH2))
        ENDIF
        STMA(J)=AP*EJ(FQ(J),FP1)*PHIK
100    CONTINUE
      ENDIF

C COMPUTE ALPHA AND RECOMPUTE STMA(NF)
```

```
      CALL INTGRL(STMA,NF,DF,ZM)
      AP=HM01**2/(4.004**2*ZM)
      DO 200 J=1,NF
       STMA(J)=AP*STMA(J)
200   CONTINUE

      RETURN
      END

C  INTERNAL FUNCTION SUBROUTINE EJ:  COMPUTES JONSWAP SPECTRUM
C
C         IN:
C      FQ...........FREQUENCY (HZ)
C      FP...........PEAK FREQUENCY (HZ)
C
C         OUT:
C      EJ...........JONSWAP SPECTRUM

      REAL FUNCTION EJ(FQ,FP)

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      TWOPI=2.*PI
      SIGA=0.07
      SIGB=0.09

C CALCULATE EP
      C1=G**2*TWOPI**(-4)
      EP=C1*FQ**(-5)
C CALCULATE PHIPM
      C=1.25*(FQ/FP)**(-4)
      IF(C.GT.150.)THEN
       C=150.
      ENDIF
      PHIPM=EXP(-C)
C JONSWAP SHAPE FUNCTION
      IF(FQ.LE.FP)THEN
       SIG=SIGA
      ELSE
       SIG=SIGB
      ENDIF
      C2=(1./(2.*SIG**2))*(FQ/FP-1.)**2
      IF(C2.GT.150.)THEN
```

```
       C2=150.
      ENDIF
      PHIJ=GAM**(EXP(-C2))
C JONSWAP SPECTRUM
      EJ=EP*PHIPM*PHIJ

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 06  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  INTGRL                                                              C
C                                                                      C
C  COMPUTES AREA UNDER THE CURVE FOR GIVEN FUNCTION                    C
C  INTEGRATION BASED ON SIMPSONS' RULE                                 C
C                                                                      C
C        IN:                                                           C
C     F(NS).........FUNCTION                                           C
C     NS...........NO. OF DATA VALUES (ODD NUMBER)                     C
C     DFS..........STEP SIZE FOR INTEGRATION                           C
C                                                                      C
C        OUT:                                                          C
C     AREA.........AREA UNDER THE CURVE                                C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE INTGRL(F,NS,DFS,AREA)

      REAL F(NS)

      SE=F(2)
      SO=0.
      DO 100 I=2,(NS-1)/2
         SE=SE+F(I*2)
         SO=SO+F(I*2-1)
100   CONTINUE
      AREA=(DFS/3.)*(F(1)+4.*SE+2.0*SO+F(NS))

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 07  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  DIRSPC                                                              C
```

```
C                                                                        C
C  COMPUTES DIRECTIONAL SPREADING PARAMETERS, SPECTRUM AND ENERGY        C
C  DISTRIBUTION FUNCTION AT DEEPER WATER DEPTH 1                         C
C                                                                        C
C        IN:                                                             C
C     NF...........NO. OF DISCRETE FREQUENCIES                           C
C     FQ(NF).......FREQUENCY DOMAIN (HZ)                                 C
C     FP1..........PEAK FREQUENCY AT DEPTH 1 (HZ)                        C
C     SMAX.........MAXIMUM DIRECTIONAL SPREADING PARAMETER               C
C     ND...........NO. OF DISCRETE DIRECTIONS                            C
C     THETA(ND)....DIRECTIONAL DOMAIN AT DEPTH 1 (RADS)                  C
C     ALPHA1.......PREDOMINANT INCIDENT WAVE DIRECTION AT DEPTH 1 (RAD)C
C     STMA(NF).....FREQUENCY SPECTRUM AT DEPTH 1 (M*M*S)                 C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                    C
C                                                                        C
C        OUT:                                                            C
C     S(NF)........DIRECTIONAL SPREADING PARAMETER                       C
C     GO(NF).......PARAMETER FOR DIRECTIONAL SPREADING FUNCTION          C
C     S1(NF,ND)....DIRECTIONAL SPECTRUM AT DEPTH 1 (M*M*S/RAD)           C
C     D1(ND).......DIRECTIONAL ENERGY DISTRIBUTION FUNCTION              C
C                  AT DEPTH 1 (M**2/RAD)                                 C
C                                                                        C
C       INTERNAL FUNCTION SUBROUTINE:  GAMMLN(XX)                        C
C                                                                        C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE DIRSPC

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER(NF=2001)
      PARAMETER(ND=181)
      DIMENSION SINTER(NF)
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/CONST/PI,G
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/MITSU/S(NF),GO(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/DIREC1/S1(NF,ND),D1(ND)

C CALCULATE DIRECTIONAL SPREADING PARAMETER S(NF)
      DO 100 J=1,NF
       IF(FQ(J).LE.FP1)THEN
        S(J)=SMAX*(FQ(J)/FP1)**5
```

```
       ELSE
        S(J)=SMAX*(FQ(J)/FP1)**(-2.5)
       ENDIF
 100  CONTINUE

C CALCULATE PARAMETER GO(NF) FOR DIRECTIONAL SPREADING FUNCTION
      DO 200 J=1,NF
       X=S(J)+1.
       Y=2*S(J)+1.
       W=2*S(J)-1.
       EXPON=2.*GAMMLN(X)-GAMMLN(Y)
       GO(J)=2.**W*EXP(EXPON)/PI
 200  CONTINUE

C CALCULATE DIRECTIONAL SPECTRUM AT DEPTH 1
      DO 300 J=1,NF
       DO 400 I=1,ND
        S1(J,I)=STMA(J)*GO(J)*COS((THETA(I)-ALPHA1)/2)**(2*S(J))
 400   CONTINUE
 300  CONTINUE

C CALCULATE DIRECTIONAL ENERGY DISTRIBUTION FUNCTION AT DEPTH 1
      DO 500 I=1,ND
       DO 600 J=1,NF
        SINTER(J)=S1(J,I)
 600   CONTINUE
       CALL INTGRL(SINTER,NF,DF,D1(I))
 500  CONTINUE

      RETURN
      END

C  INTERNAL FUNCTION SUBROUTINE TO GET NATURAL LOG OF GAMMA FUNCTION
C
C  BORROWED FROM NUMERICAL RECIPES (PRESS ET AL. 1986, P.157)
C
C        IN:
C     XX...........ARGUEMENT OF FUNCTION
C
C        OUT:
C     GAMMLN.......NATURAL LOG OF GAMMA FUNCTION

      FUNCTION GAMMLN(XX)
```

```
C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      REAL*8 COF(6),STP,HALF,ONE,FPF,X,TMP,SER
      DATA COF,STP/76.18009173D0,-86.50532033D0,24.01409822D0,
     * -1.231739516D0,.120858003D-2,-.536382D-5,2.50662827465D0/
      DATA HALF,ONE,FPF/0.5D0,1.0D0,5.5D0/

      X=XX-ONE
      TMP=X+FPF
      TMP=(X+HALF)*LOG(TMP)-TMP
      SER=ONE
      DO 100 J=1,6
       X=X+ONE
       SER=SER+COF(J)/X
  100 CONTINUE
      GAMMLN=TMP+LOG(STP*SER)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 08  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  SHOUNI                                                              C
C                                                                      C
C  COMPUTES SHOALING OF UNI-DIRECTIONAL RANDOM WAVES                   C
C  (NORMAL INCIDENCE, NO REFRACTION)                                   C
C                                                                      C
C        IN:                                                           C
C     NF...........NO. OF DISCRETE FREQUENCIES                         C
C     FQ(NF).......FREQUENCY DOMAIN (HZ)                               C
C     CG12(NF).....RATIO OF GROUP VELOCITIES AT DEPTHS 1 & 2           C
C     STMA(NF).....FREQUENCY SPECTRUM AT DEPTH 1 (M*M*S)               C
C                                                                      C
C        OUT:                                                          C
C     SUNI(NF).....SHOALED FREQUENCY SPECTRUM AT DEPTH 2 (M*M*S)       C
C     FPUNI........PEAK FREQUENCY OF FREQUENCY SPECTRUM                C
C                  AT DEPTH 2 (HZ)                                     C
C     TPUNI........PEAK PERIOD OF FREQUENCY SPECTRUM                   C
C                  AT DEPTH 2 (S)                                      C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE SHOUNI

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
```

```
      PARAMETER(NF=2001)
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/PEAKS/FPUNI,TPUNI,FPDIR,TPDIR,ALPHA2

C CALCULATE FREQUENCY SPECTRUM AT DEPTH 2
      DO 100 J=1,NF
       SUNI(J)=STMA(J)*CG12(J)
 100  CONTINUE

C CALCULATE PEAK FREQUENCY AND PERIOD AT DEPTH 2 USING
C SUBROUTINE 10 FINDMA
      CALL FINDMA(SUNI,NF,SUNIPK,LOC)
      FPUNI=FQ(LOC)
      TPUNI=1./FPUNI

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 09  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C  REFDIR                                                             C
C                                                                     C
C  COMPUTES REFRACTION OF DIRECTIONAL RANDOM WAVES                    C
C                                                                     C
C        IN:                                                          C
C     NF...........NO. OF DISCRETE FREQUENCIES                        C
C     WN21(NF).....RATIO OF WAVE NUMBERS AT DEPTHS 2 & 1              C
C     SUNI(NF).....FREQUENCY SPECTRUM AT DEPTH 2 (M*M*S)              C
C     GO(NF).......PARAMETER FOR DIRECTIONAL SPREADING FUNCTION       C
C     ND...........NO. OF DISCRETE DIRECTIONS                         C
C     THETA(ND)....DIRECTIONAL DOMAIN AT DEPTH 2 (RADS)               C
C     ALPHA1.......PREDOMINANT INCIDENT WAVE DIRECTION AT DEPTH 1 (RAD)C
C     S(NF)........DIRECTIONAL SPREADING PARAMETER                    C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                 C
C     DD...........DIRECTIONAL BANDWIDTH (RADS)                       C
C                                                                     C
C        OUT:                                                         C
C     S2(NF,ND)....DIRECTIONAL SPECTRUM AT DEPTH 2 (M*M*S/RAD)        C
C     SDIR(NF).....REFRACTED FREQUENCY SPECTRUM AT DEPTH 2 (M*M*S)    C
C     SEQU(NF).....EQUIVALENT UNI-DIRECTIONAL FREQUENCY SPECTRUM AT   C
C                  DEPTH 1 (M*M*S)                                    C
C     D2(ND).......DIRECTIONAL ENERGY DISTRIBUTION FUNCTION           C
```

```
C                 AT DEPTH 2 (M**2/RAD)                                 C
C     FPDIR........PEAK FREQUENCY OF DIRECTIONAL SPECTRUM               C
C                 AT DEPTH 2 (HZ)                                       C
C     TPDIR........PEAK PERIOD OF DIRECTIONAL SPECTRUM                  C
C                 AT DEPTH 2 (SEC)                                      C
C     ALPHA2.......PREDOMINANT INCIDENT WAVE DIRECTION AT DEPTH 2 (RAD)C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE REFDIR

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      DIMENSION S2MAX(NF),SINTER1(ND),SINTER2(NF)
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/WNUMBR/WN(2,NF),WN21(NF),CG12(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/MITSU/S(NF),G0(NF)
      COMMON/DIREC2/S2(NF,ND),D2(ND)
      COMMON/PEAKS/FPUNI,TPUNI,FPDIR,TPDIR,ALPHA2

      DO 100 J=1,NF
       S2MAX(J)=WN21(J)*SUNI(J)*G0(J)
  100 CONTINUE

      DO 200 J=1,NF
       DO 300 I=1,ND
        C=WN21(J)*SIN(THETA(I))
        IF(ABS(C).GT.1.)THEN
         S2(J,I)=0.
        ELSE
         S2(J,I)=S2MAX(J)*COS((ASIN(C)-ALPHA1)/2)**(2.*S(J))
        ENDIF
  300  CONTINUE
  200 CONTINUE

C CALCULATE FREQUENCY SPECTRUM AND ENERGY DISTRI. FCT AT DEPTH 2
      DO 400 J=1,NF
       DO 500 I=1,ND
        SINTER1(I)=S2(J,I)
  500  CONTINUE
```

```
       CALL INTGRL(SINTER1,ND,DD,SDIR(J))
 400  CONTINUE
      DO 600 I=1,ND
       DO 700 J=1,NF
        SINTER2(J)=S2(J,I)
 700   CONTINUE
       CALL INTGRL(SINTER2,NF,DF,D2(I))
 600  CONTINUE

C CALCULATE PEAKS
      CALL FINDMA(SDIR,NF,SDIRPK,LOC1)
      FPDIR=FQ(LOC1)
      TPDIR=1./FPDIR
      CALL FINDMA(D2,ND,D2PK,LOC2)
      ALPHA2=THETA(LOC2)

C CALCULATE EQUIVALENT UNI-DIRECTIONAL FREQUENCY SPECTRUM AT DEPTH 1
      DO 800 J=1,NF
       SEQU(J)=SDIR(J)/CG12(J)
 800  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 10  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  FINDMA                                                              C
C                                                                      C
C  FINDS MAXIMUM VALUE OF GIVEN FUNCTION AND ITS LOCATION              C
C                                                                      C
C        IN:                                                           C
C     F(NL).........FUNCTION                                           C
C     NL............NO. OF VALUES                                      C
C                                                                      C
C        OUT:                                                          C
C     PEAK.........PEAK VALUE                                          C
C     LOC..........LOCATION OF PEAK VALUE                              C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE FINDMA(F,NL,PEAK,LOC)

      REAL F(NL)
      PEAK=-.000001
```

```
      DO 100 I=1,NL
       IF(F(I).GT.PEAK)THEN
        PEAK=F(I)
        LOC=I
       ENDIF
 100  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 11  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  SPCPAR                                                              C
C                                                                      C
C  SUBROUTINE SPCPAR IN COX ET AL. (1991) IS MODIFIED HEREIN           C
C                                                                      C
C  COMPUTES SPECTRAL PARAMETERS FOR GIVEN FREQUENCY SPECTRUM           C
C                                                                      C
C        IN:                                                           C
C     NF...........NO. OF DISCRETE FREQUENCIES                         C
C     FQ(NF).......FREQUENCY DOMAIN (HZ)                               C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                  C
C     STMA(NF).....INCIDENT FREQUENCY SPECTRUM AT DEPTH 1 (M*M*S)      C
C     SUNI(NF).....SHOALED UNI-DIRECTIONAL FREQUENCY SPECTRUM AT       C
C                  DEPTH 2 (M*M*S)                                     C
C     SDIR(NF).....REFRACTED FREQUENCY SPECTRUM AT DEPTH 2 (M*M*S)     C
C                                                                      C
C        OUT:                                                          C
C     SP(3,NF).......STMA,SUNI & SDIR FREQUENCY SPECTRA                C
C     EP:SPECP(M,1)..SPECTRAL WIDTH PARAMETER BASED ON 2ND AND 4TH     C
C                    MOMENTS                                           C
C     VU:SPECP(M,2)..SPECTRAL WIDTH PARAMETER BASED ON 1ST AND 2ND     C
C                    MOMENTS                                           C
C     QP:SPECP(M,3)..SPECTRAL PEAKEDNESS PARAMETER                     C
C     ER:SPECP(M,4)..STANDARD DEVIATION OF FREE SURFACE DISPLACEMENT(M)C
C     HR:SPECP(M,5)..ROOT-MEAN-SQUARE WAVE HEIGHT (M)                  C
C     HMO:SPECP(M,6).SPECTRAL ESTIMATE OF SIGNIFICANT WAVE HEIGHT (M)  C
C     T1:SPECP(M,7)..MEAN PERIOD BASED ON FIRST MOMENT (S)             C
C     T2:SPECP(M,8)..MEAN PERIOD BASED ON SECOND MOMENT (S)            C
C     KP:SPECP(M,12).SPECTRAL CORRELATED PARAMETER                     C
C                                                                      C
C        IN/OUT:                                                       C
C     TP1:SPECP(1,9)......PEAK PERIOD AT DEPTH 1 (S)                   C
C     FP1:SPECP(1,10).....PEAK FREQUENCY AT DEPTH 1 (HZ)               C
```

```
C      ALPHA1:SPECP(1,11)..PREDOMINANT INCIDENT WAVE DIRECTION           C
C                          AT DEPTH 1 (RAD)                              C
C      TPUNI:SPECP(2,9)....PEAK PERIOD OF NORMALLY-INCIDENT FREQUENCY    C
C                          SPECTRUM AT DEPTH 2 (S)                       C
C      FPUNI:SPECP(2,10)...PEAK FREQUENCY OF NORMALLY-INCIDENT FREQUENCYC
C                          SPECTRUM AT DEPTH 2 (S)                       C
C      ALPHA2:SPECP(2,11)..ZERO FOR NORMALLY INCIDENT FREQUENCY SPECTRUMC
C                          AT DEPTH 2                                    C
C      TPDIR:SPECP(3,9)....PEAK PERIOD OF DIRECTIONAL SPECTRUM           C
C                          AT DEPTH 2 (S)                                C
C      FPDIR:SPECP(3,10)...PEAK FREQUENCY OF DIRECTIONAL SPECTRUM        C
C                          AT DEPTH 2 (HZ)                               C
C      ALPHA2:SPECP(3,11)..PREDOMINANT INCIDENT WAVE DIRECTION           C
C                          AT DEPTH 2 (RAD)                              C
C                                                                        C
C      M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR         C
C                                                                        C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE SPCPAR

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      DIMENSION SM(5),SINTER1(NF),SINTER2(NF)
      COMMON/CONST/PI,G
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/PEAKS/FPUNI,TPUNI,FPDIR,TPDIR,ALPHA2
      COMMON/SPCTRM/SP(3,NF)
      COMMON/SPECP/SPECP(3,12)

      DO 100 M=1,3
       DO 200 J=1,NF
        IF(M.EQ.1)THEN
         SP(M,J)=STMA(J)
        ELSEIF(M.EQ.2)THEN
         SP(M,J)=SUNI(J)
        ELSE
         SP(M,J)=SDIR(J)
        ENDIF
 200   CONTINUE
 100  CONTINUE
```

```
C SPECTRAL MOMENTS AND PEAKEDNESS PARAMETER INTEGRATION
C USING SUBROUTINE O6 INTGRL
      SINTER1(1)=0.
      DO 300 M=1,3
       DO 400 K=1,5
        IF(K.NE.4)THEN
         K1=K-1
         DO 500 J=2,NF
          SINTER1(J)=SP(M,J)*FQ(J)**(K1)
 500     CONTINUE
        ELSE
         DO 600 J=2,NF
          SINTER1(J)=FQ(J)*SP(M,J)**2
 600     CONTINUE
        ENDIF
        CALL INTGRL(SINTER1,NF,DF,SM(K))
 400   CONTINUE

C SPECTRAL STATISTICS
       SPECP(M,1)=SQRT(1-SM(3)**2/(SM(1)*SM(5)))
       SPECP(M,2)=SQRT((SM(1)*SM(3)/SM(2)**2)-1)
       SPECP(M,3)=(2./SM(1)**2)*SM(4)
       SPECP(M,4)=SQRT(SM(1))
       SPECP(M,5)=SQRT(8.*SM(1))
       SPECP(M,6)=4.004*SQRT(SM(1))
       SPECP(M,7)=SM(1)/SM(2)
       SPECP(M,8)=SQRT(SM(1)/SM(3))
       IF(M.EQ.1)THEN
        SPECP(M,9)=TP1
        SPECP(M,10)=FP1
        SPECP(M,11)=ALPHA1
       ELSEIF(M.EQ.2)THEN
        SPECP(M,9)=TPUNI
        SPECP(M,10)=FPUNI
        SPECP(M,11)=0.0
       ELSE
        SPECP(M,9)=TPDIR
        SPECP(M,10)=FPDIR
        SPECP(M,11)=ALPHA2
       ENDIF

C CORRELATED PARAMETER INTEGRATION AND CALCULATION
      SINTER1(1)=0.
```

```
      SINTER2(2)=0.
      DO 700 J=2,NF
       SINTER1(J)=SP(M,J)*COS(2*PI*FQ(J)*SPECP(M,8))
       SINTER2(J)=SP(M,J)*SIN(2*PI*FQ(J)*SPECP(M,8))
 700  CONTINUE
      CALL INTGRL(SINTER1,NF,DF,AREA1)
      CALL INTGRL(SINTER2,NF,DF,AREA2)
      SPECP(M,12)=SQRT(AREA1**2+AREA2**2)/SM(1)

 300  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 12  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C  TSRIES                                                               C
C                                                                       C
C  SUBROUTINE TIMEPH IN COX ET AL. (1991) IS MODIFIED HEREIN            C
C                                                                       C
C  COMPUTES TIME SERIES FOR GIVEN FREQUENCY SPECTRUM                    C
C                                                                       C
C        IN:                                                            C
C     NF...........NO. OF DISCRETE FREQUENCIES                          C
C     IS...........SEED VALUE FOR RANDOM NO. GENERATOR                  C
C     SP(3,NF).....STMA, SUNI & SDIR FREQUENCY SPECTRA                  C
C     DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                   C
C     NP...........EVEN NO. OF DATA POINTS IN TIME SERIES               C
C                                                                       C
C        OUT:                                                           C
C     TS(M,N)......TIME SERIES FOR STMA, SUNI & SDIR                    C
C                                                                       C
C     M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR         C
C                                                                       C
C     IMSL EXTERNAL SUBROUTINES:  RNSET,RNUN,FFT2B                      C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TSRIES

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER(NF=2001)
      PARAMETER(N=4000)
      PARAMETER(NDS=8000)
```

```
      REAL PHI(NF)
      COMPLEX CN(N),COEF(NDS,1),AFFT(NDS,1)
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISTIM/NP,DT,TIME(N)
      COMMON/SPCTRM/SP(3,NF)
      COMMON/SERIES/TS(3,N)

      TWOPI=2.*PI

C GENERATE RANDOM NUMBERS FROM 0 TO 1
      CALL RNSET(IS)
      CALL RNUN(NF-1,PHI)

C FILL UP COMPLEX COEFFICIENTS
C                               AVERAGE VALUE
      DO 200 M=1,3
       CN(1)=CMPLX(0.0,0.0)
C                               FIRST HALF OF ARRAY
       DO 300 K=2,NF-1
        PHX=TWOPI*PHI(K-1)
        CX=SQRT(2.*SP(M,K)*DF)
        CN(K)=.5*CX*CMPLX(COS(PHX),SIN(PHX))
 300   CONTINUE
C                               AT NYQUIST FREQUENCY
       PHX=TWOPI*PHI(NF-1)
       CX=SQRT(2.*SP(M,NF)*DF)
       CN(NF)=CX*CMPLX(COS(PHX),0.0)
C                               SECOND HALF OF ARRAY
       DO 400 K=NF+1,NP
        NN=NP-K+2
        PHX=TWOPI*PHI(NN-1)
        CX=SQRT(2.*SP(M,NN)*DF)
        CN(K)=.5*CX*CMPLX(COS(PHX),-SIN(PHX))
 400   CONTINUE
C                               INVERSE FOURIER TRANSFORM
       DO 500 K=1,NP
        COEF(K,1)=CN(K)
 500   CONTINUE
       NRCOEF=NP
       NCCOEF=1
       LDCOEF=NDS
       LDA=NDS
```

```
      CALL FFT2B(NRCOEF,NCCOEF,COEF,LDCOEF,AFFT,LDA)
C                                  TAKE REAL PART OF TIME SERIES
      DO 600 K=1,NP
       TS(M,K)=REAL(AFFT(K,1))
 600  CONTINUE
 200 CONTINUE

     RETURN
     END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 13  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  TIMPAR                                                              C
C                                                                      C
C  SUBROUTINE TIMPAR IN COX ET AL. (1991) IS MODIFIED HEREIN           C
C                                                                      C
C  COMPUTES PARAMETERS FOR GIVEN TIME SERIES BY ZERO-UPCROSS METHOD    C
C                                                                      C
C        IN:                                                           C
C     TS(M,N)......TIME SERIES FOR STMA, SUNI & SDIR (M)               C
C     NP...........EVEN NUMBER OF DATA POINTS                          C
C     DT...........TIME STEP (DELTA T)                                 C
C                                                                      C
C        OUT:                                                          C
C     SD:TIMEP(M,1)...AVERAGE OF TS (SETUP OR SETDOWN) (M)             C
C     ER:TIMEP(M,2)...STANDARD DEVIATION OF TIME SERIES (M)            C
C     NZ:TIMEP(M,3)...NUMBER OF ZERO-UPCROSSING WAVES                  C
C     HB:TIMEP(M,4)...MEAN WAVE HEIGHT (M)                             C
C     TB:TIMEP(M,5)...MEAN WAVE PERIOD (S)                             C
C     HV:TIMEP(M,6)...ROOT-MEAN-SQUARE WAVE HEIGHT (M)                 C
C     HS:TIMEP(M,7)...SIGNIFICANT WAVE HEIGHT (M)                      C
C     T3:TIMEP(M,8)...SIGNIFICANT WAVE PERIOD (S)                      C
C     HT:TIMEP(M,9)...MEAN HEIGHT OF ONE-TENTH HIGHEST WAVES (M)       C
C     TT:TIMEP(M,10)..MEAN PERIOD OF ONE-TENTH HIGHEST WAVES (S)       C
C     NK:TIMEP(M,11)..NUMBER OF RUNS EXCEEDING HS                      C
C     TIMEP(M,12).....MEAN RUN LENGTH                                  C
C     HRK(M,NZ).......RANKED WAVE HEIGHTS WITH HRK(1) THE HIGHEST (M)  C
C     TRK(M,NZ).......WAVE PERIODS FOR RANKED WAVE HEIGHTS (S)         C
C     LRN(M,NK).......RUN LENGTH OF WAVE HEIGHTS EXCEEDING HS          C
C                                                                      C
C     M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR        C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
      SUBROUTINE TIMPAR

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NDS=8000)
      PARAMETER (NDZ=500)
      PARAMETER (N=4000)
      REAL ATS(NDS),HGT(NDZ)
      REAL TMZERO(NDZ),T(NDZ),TSMAX(NDZ),TSMIN(NDZ)
      INTEGER IZERO(NDZ),JMAX(NDZ),JMIN(NDZ),IRK(NDZ)
      LOGICAL SORTED
      COMMON/DISTIM/NP,DT,TIME(N)
      COMMON/SERIES/TS(3,N)
      COMMON/UPCROS/NZ(3),HRK(3,NDZ),TRK(3,NDZ),NK(3),LRN(3,NDZ)
      COMMON/TIMEPR/TIMEP(3,12)

      TM=NP*DT
C ADJUST TIME SERIES TO MAKE PERIODIC OVER TIME FOR M=1,2 AND 3
      DO 50 M=1,3
       DO 100 I=1,NP
        ATS(I)=TS(M,I)
 100   CONTINUE
       ATS(NP+1)=TS(M,1)
C CORRECT FOR MEAN WATER LEVEL
       SUM=0.0
       DO 150 I=1,NP
        SUM=SUM+ATS(I)
 150   CONTINUE
       SD=SUM/FLOAT(NP)
       DO 200 I=1,NP+1
        ATS(I)=ATS(I)-SD
 200   CONTINUE
       TIMEP(M,1)=SD
C COMPUTE STANDARD DEVIATION OF ETA(T)
       SUM=0.0
       DO 250 I=1,NP
        SUM=SUM+(ATS(I)*ATS(I))
 250   CONTINUE
       ER=SQRT(SUM/FLOAT(NP))
       TIMEP(M,2)=ER
C ZERO-UPCROSSING POINTS
       NZ(M)=0
       DO 300 J=1,NP
        IF(ATS(J).EQ.0.0)THEN
         NZ(M)=NZ(M)+1
```

```
          IZERO(NZ(M))=J+1
          TMZERO(NZ(M))=(J-1)*DT
         ELSEIF(ATS(J).LT.0.0.AND.ATS(J+1).GT.0.0)THEN
          NZ(M)=NZ(M)+1
          IZERO(NZ(M))=J+1
          TMZERO(NZ(M))=(J-1)*DT+(-ATS(J)/(ATS(J+1)-ATS(J)))*DT
         ENDIF
 300    CONTINUE
        TIMEP(M,3)=FLOAT(NZ(M))
C CALCULATE WAVE PERIOD, T, OF EACH WAVE
        DO 350 I=1,NZ(M)-1
         T(I)=TMZERO(I+1)-TMZERO(I)
 350    CONTINUE
        T(NZ(M))=(TM-TMZERO(NZ(M)))+TMZERO(1)
C  NEED TO FIND TSMAX, TSMIN
        DO 400 I=1,NZ(M)
         TSMAX(I)=0.0
         TSMIN(I)=0.0
         J1=IZERO(I)
         IF(I.EQ.NZ(M))THEN
          J2=NP+IZERO(1)-1
         ELSE
          J2=IZERO(I+1)-1
         ENDIF
         DO 450 J=J1,J2
          IF(J.GT.NP)THEN
           JT=J-NP
          ELSE
           JT=J
          ENDIF
          IF(ATS(JT).GT.TSMAX(I))THEN
           TSMAX(I)=ATS(JT)
           JMAX(I)=JT
          ENDIF
          IF(ATS(JT).LT.TSMIN(I))THEN
           TSMIN(I)=ATS(JT)
           JMIN(I)=JT
          ENDIF
 450     CONTINUE
 400    CONTINUE
C IMPROVE ESTIMATES W/ PARABOLIC CURVE
        DO 500 I=1,NZ(M)
         J=JMAX(I)
         J1=J-1
```

```
        IF(J1.LT.1)THEN
         J1=NP
        ENDIF
        TS1=ATS(J1)
        TS2=ATS(J)
        TS3=ATS(J+1)
        TSMAX(I)=TS2-(TS3-TS1)**2/(8.*(TS1-2*TS2+TS3))
        J=JMIN(I)
        J1=J-1
        IF(J1.LT.1)THEN
         J1=NP
        ENDIF
        TS1=ATS(J1)
        TS2=ATS(J)
        TS3=ATS(J+1)
        TSMIN(I)=TS2-(TS3-TS1)**2/(8.*(TS1-2*TS2+TS3))
C WAVE HEIGHT, HGT, OF EACH WAVE
        HGT(I)=TSMAX(I)-TSMIN(I)
 500   CONTINUE
C STATISTICS OF INDIVIDUAL WAVE HEIGHTS
       SUM=0.0
       SUMHB=0.0
       SUMHV=0.0
       DO 550 I=1,NZ(M)
        SUM=SUM+T(I)
        SUMHB=SUMHB+HGT(I)
        SUMHV=SUMHV+HGT(I)*HGT(I)
 550   CONTINUE
       TB=SUM/FLOAT(NZ(M))
       HB=SUMHB/FLOAT(NZ(M))
       HV=SQRT(SUMHV/FLOAT(NZ(M)))
       TIMEP(M,5)=TB
       TIMEP(M,4)=HB
       TIMEP(M,6)=HV
C SORTING ROUTINE FOR WAVE HEIGHT RANKING
C                              SET UP HRANK, TRANK, IRANK ARRAYS
       DO 600 I=1,NZ(M)
        IRK(I)=I
        HRK(M,I)=HGT(I)
        TRK(M,I)=T(I)
 600   CONTINUE
       SORTED=.FALSE.
       IPASS=0
 650   IF(.NOT.SORTED)THEN
```

```
        IPASS=IPASS+1
        SORTED=.TRUE.
        DO 700 I=1,NZ(M)-IPASS
         IF(HGT(IRK(I)).LT.HGT(IRK(I+1)))THEN
          ITEMP=IRK(I)
          IRK(I)=IRK(I+1)
          IRK(I+1)=ITEMP
          HTEMP=HRK(M,I)
          HRK(M,I)=HRK(M,I+1)
          HRK(M,I+1)=HTEMP
          TTEMP=TRK(M,I)
          TRK(M,I)=TRK(M,I+1)
          TRK(M,I+1)=TTEMP
          SORTED=.FALSE.
         ENDIF
 700    CONTINUE
        GOTO 650
       ENDIF
C REPRESENTATIVE WAVE HEIGHT AND PERIOD
       ITHIRD=NZ(M)/3
       ITENTH=NZ(M)/10
       HS=0.0
       T3=0.0
       DO 750 I=1,ITHIRD
        HS=HS+HRK(M,I)
        T3=T3+TRK(M,I)
 750   CONTINUE
       HS=HS/FLOAT(ITHIRD)
       T3=T3/FLOAT(ITHIRD)
       TIMEP(M,7)=HS
       TIMEP(M,8)=T3
       HT=0.0
       TT=0.0
       DO 800 I=1,ITENTH
        HT=HT+HRK(M,I)
        TT=TT+TRK(M,I)
 800   CONTINUE
       HT=HT/FLOAT(ITENTH)
       TT=TT/FLOAT(ITENTH)
       TIMEP(M,9)=HT
       TIMEP(M,10)=TT
C RUN LENGTH OF WAVE HEIGHTS EXCEEDING HS
       NK(M)=0
       NCOUNT=0
```

```
      I=1
 850    IF(I.LE.NZ(M))THEN
         IF(HGT(I).GT.HS)THEN
          NK(M)=NK(M)+1
          NCOUNT=NCOUNT+1
 900      IF(HGT(I+NCOUNT).GT.HS)THEN
           NCOUNT=NCOUNT+1
           GO TO 900
          ENDIF
          LRN(M,NK(M))=NCOUNT
          I=I+NCOUNT
          NCOUNT=0
         ENDIF
         I=I+1
         GOTO 850
        ENDIF
      TIMEP(M,11)=FLOAT(NK(M))
C CALCULATE MEAN RUN LENGTH
      SUMLRN=0.0
      DO 950 J=1,NK(M)
       SUMLRN=SUMLRN+LRN(M,J)
 950  CONTINUE
      TIMEP(M,12)=SUMLRN/FLOAT(NK(M))

 50   CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 14  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C  WBREAK                                                             C
C                                                                     C
C  COMPUTES BREAKING OF INDIVIDUAL WAVES AT SHALLOWER DEPTH 2          C
C                                                                     C
C        IN:                                                          C
C     H(2)............SHALLOWER WATER DEPTH 2 (M)                     C
C     SLOPE...........BOTTOM SLOPE AT DEPTH 2                         C
C     NZ:TIMEP(M,3)...NUMBER OF ZERO-UPCROSSING WAVES                 C
C     HRK(M,NZ).......RANKED WAVE HEIGHTS WITH HRK(1) THE HIGHEST (M) C
C     TRK(M,NZ).......WAVE PERIODS FOR RANKED WAVE HEIGHTS (S)        C
C                                                                     C
C        OUT:                                                         C
C     HBREAK(M,NZ)....BREAKER HEIGHT (M)                              C
```

```
C     IBREAK(M,NZ)....BREAKER INDICATOR: 1-BREAKING O-NOT BREAKING      C
C                                                                       C
C     M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR                         C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE WBREAK

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS:
      PARAMETER (NDZ=500)
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/UPCROS/NZ(3),HRK(3,NDZ),TRK(3,NDZ),NK(3),LRN(3,NDZ)
      COMMON/WAVEBK/HBREAK(3,NDZ),IBREAK(3,NDZ)

C SHOALED UNI-DIRECTIONAL WAVES AND REFRACTED DIRECTIONAL WAVES
C WILL BE EXAMINED TO DETERMINE BREAKING OF INDIVIDUAL WAVES
C USING EMPIRICAL CRITERION FOR REGULAR WAVES

C CALCULATE CONSTANTS
      A1=.17*G/2./PI
      A2=(3.*H(2)*PI**2)*(1+15*SLOPE**(4./3.))/G

C CALCULATE BREAKING HEIGHT AND INDICATOR
      DO 100 M=2,3
       DO 200 I=1,NZ(M)
        HBREAK(M,I)=A1*(1-EXP(-A2/TRK(M,I)**2))*TRK(M,I)**2
        IF(HRK(M,I).GE.HBREAK(M,I))THEN
         IBREAK(M,I)=1
        ELSE
         IBREAK(M,I)=0
        ENDIF
 200   CONTINUE
 100  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 15  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C  OFILES                                                               C
C                                                                       C
C  OPENS ALL FILES FOR OUTPUT                                           C
C                                                                       C
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE OFILES

C OPEN ALL FILES
      OPEN(UNIT=11, FILE= '/INPUT OUT A')
      OPEN(UNIT=12, FILE= '/FQ DATA A')
      OPEN(UNIT=13, FILE= '/ANG DATA A')
      OPEN(UNIT=14, FILE= '/TIME DATA A')
      OPEN(UNIT=15, FILE= '/SPECP OUT A')
      OPEN(UNIT=16, FILE= '/TIMEP OUT A')
      OPEN(UNIT=17, FILE= '/UNIBRK OUT A')
      OPEN(UNIT=18, FILE= '/DIRBRK OUT A')
      OPEN(UNIT=19, FILE= '/RUNLTH OUT A')
      OPEN(UNIT=20, FILE= '/STMA DATA A')
      OPEN(UNIT=21, FILE= '/SUNI DATA A')
      OPEN(UNIT=22, FILE= '/SDIR DATA A')
      OPEN(UNIT=23, FILE= '/SEQU DATA A')
      OPEN(UNIT=24, FILE= '/D1 DATA A')
      OPEN(UNIT=25, FILE= '/D2 DATA A')
      OPEN(UNIT=26, FILE= '/DIRSP1 DATA A')
      OPEN(UNIT=27, FILE= '/DIRSP2 DATA A')
      OPEN(UNIT=28, FILE= '/TS1 DATA A')
      OPEN(UNIT=29, FILE= '/TS2 DATA A')
      OPEN(UNIT=30, FILE= '/TS3 DATA A')

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 16  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C  TABINP                                                               C
C                                                                       C
C  OUPUTS INPUT AND DISCRETIZATION PARAMETERS AND                       C
C  RESPECTIVE FILE NAMES                                                C
C                                                                       C
C        IN/OUT:                                                        C
C     H(M).........WATER DEPTHS 1 & 2 (M=1,2) (M)                       C
C     HM01.........SPECTRAL ESTIMATE OF SIGNIFICANT WAVE HEIGHT AT      C
C                  DEPTH 1 (M)                                          C
```

```
C      TP1..........PEAK PERIOD AT DEPTH 1 (S)                                C
C      GAM..........PEAK ENHANCEMENT FACTOR FOR JONSWAP SPECTRUM              C
C      IDEEP........WATER DEPTH IDENTIFIER: SET IDEEP=1 FOR DEEP WATER        C
C                   SPECTRUM                                                  C
C      SMAX.........MAX. VALUE OF DIRECTIONAL SPREADING PARAMETER, S,         C
C                   AT DEPTH 1                                                C
C      ALPHA1.......PREDOMINANT INCIDENT WAVE DIRECTION AT DEPTH 1 (RAD)C
C      SLOPE........BOTTOM SLOPE AT DEPTH 2                                   C
C      IS...........SEED VALUE FOR RANDOM NO. GENERATOR                       C
C      NF...........NO. OF DISCRETE FREQUENCIES                               C
C      DF...........FREQUENCY BANDWIDTH (DELTA F) (HZ)                        C
C      NP...........EVEN NO. OF DATA POINTS IN TIME SERIES                    C
C      DT...........TIME STEP (DELTA T)                                       C
C      ND...........NO. OF DISCRETE DIRECTIONS                                C
C      DD...........DIRECTIONAL BANDWIDTH (RADS)                              C
C                                                                             C
C         OUT:                                                                C
C      INPUT OUT....OUTPUT (DATA) FILE NAME FOR INPUT AND                     C
C                   DISCRETIZATION PARAMETERS (UNIT=11)                       C
C      FQ DATA......OUTPUT (PLOT) FILE NAME FOR FREQUENCY DOMAIN              C
C                   (UNIT=12)                                                 C
C      ANG DATA.....OUTPUT (PLOT) FILE NAME FOR DIRECTIONAL DOMAIN            C
C                   (UNIT=13)                                                 C
C      TIME DATA....OUTPUT (PLOT) FILE NAME FOR TIME DOMAIN (UNIT=14)         C
C                                                                             C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TABINP

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      PARAMETER (N=4000)
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/CONST/PI,G
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISTIM/NP,DT,TIME(N)
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/MINMAX/FMIN,FMAX,TMIN,TMAX

C OPEN (DATA) FILE INPUT OUT FOR PARAMETERS (UNIT=11)
      WRITE(11,*) COMMEN1
```

```
      WRITE(11,*) COMMEN2
      WRITE(11,*) COMMEN3
      WRITE(11,*) COMMEN4
      WRITE(11,*) COMMEN5
      WRITE(11,*)  ' '
      WRITE(11,*)  'INPUT PARAMETERS'
      WRITE(11,*)  ' '
      WRITE(11,10) H(1)
      WRITE(11,11) H(2)
      WRITE(11,12) HMO1,TP1
      WRITE(11,13) GAM
      WRITE(11,14) IDEEP
      WRITE(11,15) SMAX
      WRITE(11,16) ALPHA1*180./PI
      WRITE(11,17) SLOPE
      WRITE(11,18) IS
      WRITE(11,19) NF
      WRITE(11,20) ND
      WRITE(11,21) FMIN,FMAX
      WRITE(11,22) TMIN*180./PI,TMAX*180./PI
      WRITE(11,*) ' '
      WRITE(11,*) 'FILE NAME       OUTPUT'
      WRITE(11,*) '---------       -----------'
      WRITE(11,*) 'FQ DATA         FRQ. DOMAIN'
      WRITE(11,*) 'ANG DATA        DIR. DOMAIN'
      WRITE(11,*) 'TIME DATA       TIME DOMAIN'
 10   FORMAT(F12.8,22X,'--> H1 (M)')
 11   FORMAT(F12.8,22X,'--> H2 (M)')
 12   FORMAT(F12.8,5X,F12.8,5X,'--> HMO1 (M), TP1 (S)')
 13   FORMAT(F12.8,22X,'--> GAMMA')
 14   FORMAT(I5,29X,'--> IDEEP')
 15   FORMAT(F12.8,22X,'--> SMAX')
 16   FORMAT(F12.8,22X,'--> ALPHA1 (DEG)')
 17   FORMAT(F12.8,22X,'--> SLOPE')
 18   FORMAT(I5,29X,'--> IS')
 19   FORMAT(I5,29X,'--> NO. OF FRQ.')
 20   FORMAT(I5,29X,'--> NO. OF DIR.')
 21   FORMAT(F12.8,5X,F12.8,5X,'--> FMIN (HZ), FMAX (HZ)')
 22   FORMAT(F12.8,5X,F12.8,5X,'--> THETAMIN (DEG), THETAMAX (DEG)')

C OPEN (PLOT) FILE FQ DATA, ANG DATA AND TIME DATA FOR DOMAINS
C (UNITS 12-14)
      WRITE(12,23) (FQ(J),J=1,NF)
      WRITE(13,23) (THETA(I)*180./PI,I=1,ND)
```

```
      WRITE(14,23) (TIME(K),K=1,NP)
 23   FORMAT(E17.9)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 17  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C  TABSPC                                                               C
C                                                                       C
C  OUPUTS SPECTRAL PARAMETERS                                           C
C                                                                       C
C        IN/OUT:                                                        C
C     H(M)................WATER DEPTHS 1 & 2 (M=1,2) (M)                C
C     EP:SPECP(M,1).......SPECTRAL WIDTH PARAMETER BASED ON 2ND         C
C                         AND 4TH MOMENTS                               C
C     VU:SPECP(M,2).......SPECTRAL WIDTH PARAMETER BASED ON 1ST         C
C                         AND 2ND MOMENTS                               C
C     QP:SPECP(M,3).......SPECTRAL PEAKEDNESS PARAMETER                 C
C     ER:SPECP(M,4).......STANDARD DEVIATION OF FREE                    C
C                         SURFACE DISPLACEMENT (M)                      C
C     HR:SPECP(M,5).......ROOT-MEAN-SQUARE WAVE HEIGHT (M)              C
C     HMO:SPECP(M,6)......SPECTRAL ESTIMATE OF SIGNIFICANT WAVE         C
C                         HEIGHT (M)                                    C
C     T1:SPECP(M,7).......MEAN PERIOD BASED ON FIRST MOMENT (S)         C
C     T2:SPECP(M,8).......MEAN PERIOD BASED ON SECOND MOMENT (S)        C
C     TP1:SPECP(1,9)......PEAK PERIOD AT DEPTH 1 (S)                    C
C     FP1:SPECP(1,10).....PEAK FREQUENCY AT DEPTH 1 (HZ)                C
C     ALPHA1:SPECP(1,11)..PREDOMINANT INCIDENT WAVE DIRECTION           C
C                         AT DEPTH 1 (RAD)                              C
C     TPUNI:SPECP(2,9)....PEAK PERIOD OF NORMALLY-INCIDENT FREQUENCY    C
C                         SPECTRUM AT DEPTH 2 (S)                       C
C     FPUNI:SPECP(2,10)...PEAK FREQUENCY OF NORMALLY-INCIDENT FREQUENCYC
C                         SPECTRUM AT DEPTH 2 (S)                       C
C     ALPHA2:SPECP(2,11)..ZERO FOR NORMALLY INCIDENT FREQUENCY SPECTRUMC
C                         AT DEPTH 2                                    C
C     TPDIR:SPECP(3,9)....PEAK PERIOD OF DIRECTIONAL SPECTRUM           C
C                         AT DEPTH 2 (S)                                C
C     FPDIR:SPECP(3,10)...PEAK FREQUENCY OF DIRECTIONAL SPECTRUM        C
C                         AT DEPTH 2 (HZ)                               C
C     ALPHA2:SPECP(3,11)..PREDOMINANT INCIDENT WAVE DIRECTION           C
C                         AT DEPTH 2 (RAD)                              C
C     KP:SPECP(M,12)......SPECTRAL CORRELATED PARAMETER                 C
C                                                                       C
```

```
C     M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR          C
C                                                                        C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TABSPC

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/SPECP/SPECP(3,12)

C WRITE SPECTRAL PARAMETERS TO (DATA) FILE SPECP OUT (UNIT=15)
      WRITE(15,*) COMMEN1
      WRITE(15,*) COMMEN2
      WRITE(15,*) COMMEN3
      WRITE(15,*) COMMEN4
      WRITE(15,*) COMMEN5
      WRITE(15,*)  ' '
      WRITE(15,*)  'SPECTRAL PARAMETERS'
      WRITE(15,*)  ' '
      WRITE(15,*)  ' SPECTRAL     INCIDENT   SHOALED    REFRACTED'
      WRITE(15,*)  'PARAMETERS    SPECTRUM   SPECTRUM   SPECTRUM'
      WRITE(15,*)  '---------------------------------------------'
      WRITE(15,10) H(1),H(2),H(2)
      WRITE(15,*)  '---------------------------------------------'
      WRITE(15,11) SPECP(1,1),SPECP(2,1),SPECP(3,1)
      WRITE(15,12) SPECP(1,2),SPECP(2,2),SPECP(3,2)
      WRITE(15,13) SPECP(1,3),SPECP(2,3),SPECP(3,3)
      WRITE(15,14) SPECP(1,4),SPECP(2,4),SPECP(3,4)
      WRITE(15,15) SPECP(1,5),SPECP(2,5),SPECP(3,5)
      WRITE(15,16) SPECP(1,6),SPECP(2,6),SPECP(3,6)
      WRITE(15,17) SPECP(1,7),SPECP(2,7),SPECP(3,7)
      WRITE(15,18) SPECP(1,8),SPECP(2,8),SPECP(3,8)
      WRITE(15,19) SPECP(1,9),SPECP(2,9),SPECP(3,9)
      WRITE(15,20) SPECP(1,10),SPECP(2,10),SPECP(3,10)
      WRITE(15,21) SPECP(1,11),SPECP(2,11),SPECP(3,11)
      WRITE(15,22) SPECP(1,12),SPECP(2,12),SPECP(3,12)
 10   FORMAT(' DEPTH (M)    ',F8.5,3X,F8.5,3X,F8.5)
 11   FORMAT('     EP',7X,F8.5,3X,F8.5,3X,F8.5)
 12   FORMAT('     VU',7X,F8.5,3X,F8.5,3X,F8.5)
 13   FORMAT('     Qp',7X,F8.5,3X,F8.5,3X,F8.5)
 14   FORMAT('     ER',7X,F8.5,3X,F8.5,3X,F8.5)
 15   FORMAT('     HR',7X,F8.5,3X,F8.5,3X,F8.5)
```

```
16    FORMAT('    HMO',6X,F8.5,3X,F8.5,3X,F8.5)
17    FORMAT('    T1',7X,F8.5,3X,F8.5,3X,F8.5)
18    FORMAT('    T2',7X,F8.5,3X,F8.5,3X,F8.5)
19    FORMAT('    TP',7X,F8.5,3X,F8.5,3X,F8.5)
20    FORMAT('    FP',7X,F8.5,3X,F8.5,3X,F8.5)
21    FORMAT('    ALPHA',4X,F8.5,3X,F8.5,3X,F8.5)
22    FORMAT('    KAPPA',4X,F8.5,3X,F8.5,3X,F8.5)
      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 18  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                      C
C  TABTIM                                                              C
C                                                                      C
C  OUPUTS TIME SERIES PARAMETERS                                       C
C                                                                      C
C         IN/OUT:                                                      C
C      H(M)............WATER DEPTHS 1 & 2 (M=1,2) (M)                  C
C      SD:TIMEP(M,1)...AVERAGE OF TS (SETUP OR SETDOWN) (M)            C
C      ER:TIMEP(M,2)...STANDARD DEVIATION OF TIME SERIES (M)           C
C      NZ:TIMEP(M,3)...NUMBER OF ZERO-UPCROSSING WAVES                 C
C      HB:TIMEP(M,4)...MEAN WAVE HEIGHT (M)                            C
C      TB:TIMEP(M,5)...MEAN WAVE PERIOD (S)                            C
C      HV:TIMEP(M,6)...ROOT-MEAN-SQUARE WAVE HEIGHT (M)                C
C      HS:TIMEP(M,7)...SIGNIFICANT WAVE HEIGHT OF 1/3 HIGHEST WAVES (M) C
C      T3:TIMEP(M,8)...SIGNIFICANT WAVE PERIOD OF 1/3 HIGHEST WAVES (S) C
C      HT:TIMEP(M,9)...MEAN HEIGHT OF ONE-TENTH HIGHEST WAVES (M)      C
C      TT:TIMEP(M,10)..MEAN PERIOD OF ONE-TENTH HIGHEST WAVES (S)      C
C      NK:TIMEP(M,11)..NUMBER OF RUNS EXCEEDING HS                     C
C      TIMEP(M,12).....MEAN RUN LENGTH                                 C
C                                                                      C
C      M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR       C
C                                                                      C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TABTIM

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/TIMEPR/TIMEP(3,12)

C WRITE TIME PARAMETERS TO (DATA) FILE TIMEP OUT (UNIT=16)
```

```
      WRITE(16,*) COMMEN1
      WRITE(16,*) COMMEN2
      WRITE(16,*) COMMEN3
      WRITE(16,*) COMMEN4
      WRITE(16,*) COMMEN5
      WRITE(16,*)  ' '
      WRITE(16,*)  'TIME SERIES PARAMETERS'
      WRITE(16,*)  ' '
      WRITE(16,*)  'TIME SERIES   INCIDENT   SHOALED    REFRACTED'
      WRITE(16,*)  'PARAMETERS    SPECTRUM   SPECTRUM   SPECTRUM '
      WRITE(16,*)  '---------------------------------------------'
      WRITE(16,10) H(1),H(2),H(2)
      WRITE(16,*)  '---------------------------------------------'
      WRITE(16,11) TIMEP(1,1),TIMEP(2,1),TIMEP(3,1)
      WRITE(16,12) TIMEP(1,2),TIMEP(2,2),TIMEP(3,2)
      WRITE(16,13) TIMEP(1,3),TIMEP(2,3),TIMEP(3,3)
      WRITE(16,14) TIMEP(1,4),TIMEP(2,4),TIMEP(3,4)
      WRITE(16,15) TIMEP(1,5),TIMEP(2,5),TIMEP(3,5)
      WRITE(16,16) TIMEP(1,6),TIMEP(2,6),TIMEP(3,6)
      WRITE(16,17) TIMEP(1,7),TIMEP(2,7),TIMEP(3,7)
      WRITE(16,18) TIMEP(1,8),TIMEP(2,8),TIMEP(3,8)
      WRITE(16,19) TIMEP(1,9),TIMEP(2,9),TIMEP(3,9)
      WRITE(16,20) TIMEP(1,10),TIMEP(2,10),TIMEP(3,10)
      WRITE(16,21) TIMEP(1,11),TIMEP(2,11),TIMEP(3,11)
      WRITE(16,22) TIMEP(1,12),TIMEP(2,12),TIMEP(3,12)
 10   FORMAT(' DEPTH (M)     ',F8.5,3X,F8.5,3X,F8.5)
 11   FORMAT('     SD',8X,F8.5,3X,F8.5,3X,F8.5)
 12   FORMAT('     ER',8X,F8.5,3X,F8.5,3X,F8.5)
 13   FORMAT('     NZ',8X,F8.3,3X,F8.3,3X,F8.3)
 14   FORMAT('     HB',8X,F8.5,3X,F8.5,3X,F8.5)
 15   FORMAT('     TB',8X,F8.5,3X,F8.5,3X,F8.5)
 16   FORMAT('     HV',8X,F8.5,3X,F8.5,3X,F8.5)
 17   FORMAT('     HS',8X,F8.5,3X,F8.5,3X,F8.5)
 18   FORMAT('     T3',8X,F8.5,3X,F8.5,3X,F8.5)
 19   FORMAT('     HT',8X,F8.5,3X,F8.5,3X,F8.5)
 20   FORMAT('     TT',8X,F8.5,3X,F8.5,3X,F8.5)
 21   FORMAT('     NK',8X,F8.3,3X,F8.3,3X,F8.3)
 22   FORMAT('     M.R.L.',4X,F8.5,3X,F8.5,3X,F8.5)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 19  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
```

```
C  TABIWS                                                        C
C                                                                C
C  OUPUTS INDIVIDUAL WAVE STATISTICS                             C
C                                                                C
C        IN/OUT:                                                 C
C     H(M)............WATER DEPTHS 1 & 2 (M=1,2) (M)             C
C     NZ:TIMEP(M,3)...NUMBER OF ZERO-UPCROSSING WAVES            C
C     HRK(M,NZ).......RANKED WAVE HEIGHTS WITH HRK(1) THE HIGHEST (M)  C
C     TRK(M,NZ).......WAVE PERIODS FOR RANKED WAVE HEIGHTS (S)   C
C     HBREAK(M,NZ)....BREAKER HEIGHT (M)                         C
C     IBREAK(M,NZ)....BREAKER INDICATOR: 1-BREAKING 0-NOT BREAKING   C
C                                                                C
C     M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR  C
C                                                                C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TABIWS

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      PARAMETER (NDZ=500)
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/INPUT/H(2),HMO1,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/UPCROS/NZ(3),HRK(3,NDZ),TRK(3,NDZ),NK(3),LRN(3,NDZ)
      COMMON/WAVEBK/HBREAK(3,NDZ),IBREAK(3,NDZ)

C WRITE WAVE STATISTICS FOR SHOALED UNI-DIR SPECTRUM TO (DATA) FILE
C UNIBRK OUT (UNIT=17)
      WRITE(17,*) COMMEN1
      WRITE(17,*) COMMEN2
      WRITE(17,*) COMMEN3
      WRITE(17,*) COMMEN4
      WRITE(17,*) COMMEN5
      WRITE(17,*)  ' '
      WRITE(17,*)  'WAVE STATISTICS FOR SHOALED SPECTRUM'
      WRITE(17,*)  ' '
      WRITE(17,*)  '         INC SPECTRUM      SHOALED SPECTRUM'
      WRITE(17,*)  '---------------------------------------------'
      WRITE(17,10) H(1),H(2)
      WRITE(17,*)  '---------------------------------------------'
      WRITE(17,*)  '  RANK   Tr      Hr      Tr      Hr      Hb   Ib'
      WRITE(17,*)  '---------------------------------------------'
      IF(NZ(2).GE.NZ(1))THEN
       N=NZ(2)
```

```
      ELSE
       N=NZ(1)
      ENDIF
      DO 200 I=1,N
       WRITE(17,11) I,TRK(1,I),HRK(1,I),TRK(2,I),
     * HRK(2,I),HBREAK(2,I),IBREAK(2,I)
 200  CONTINUE
 10   FORMAT(' DEPTH(M)    ',F8.5,11X,F8.5)
 11   FORMAT(4X,I3,1X,F6.3,1X,F6.3,1X,F6.3,1X,F6.3,1X,F6.3,1X,I2)

C WRITE WAVE STATISTICS FOR REFRACTED DIRECTIONAL SPECTRUM TO
C (DATA) FILE DIRBRK.OUT (UNIT=18)
      WRITE(18,*) COMMEN1
      WRITE(18,*) COMMEN2
      WRITE(18,*) COMMEN3
      WRITE(18,*) COMMEN4
      WRITE(18,*) COMMEN5
      WRITE(18,*)  ' '
      WRITE(18,*)  'WAVE STATISTICS FOR REFRACTED SPECTRUM'
      WRITE(18,*)  ' '
      WRITE(18,*)  '         INC SPECTRUM     REFRACTED SPECTRUM'
      WRITE(18,*)  '-----------------------------------------------'
      WRITE(18,10) H(1),H(2)
      WRITE(18,*)  '-----------------------------------------------'
      WRITE(18,*)  '  RANK  Tr     Hr     Tr     Hr      Hb    Ib'
      WRITE(18,*)  '-----------------------------------------------'
      IF(NZ(3).GE.NZ(1))THEN
       N=NZ(3)
      ELSE
       N=NZ(1)
      ENDIF
      DO 400 I=1,N
       WRITE(18,11)I,TRK(1,I),HRK(1,I),TRK(3,I),HRK(3,I),
     * HBREAK(3,I),IBREAK(3,I)
 400  CONTINUE

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 20  CCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C  TABRUN                                                             C
C                                                                     C
C  OUPUTS RUN LENGTH STATISTICS                                       C
```

```
C                                                                    C
C        IN/OUT:                                                     C
C      H(M)............WATER DEPTHS 1 & 2 (M=1,2) (M)                C
C      NK:TIMEP(M,11)..NUMBER OF RUNS                                C
C      LRN(M,NK).......RUN LENGTH OF WAVE HEIGHTS EXCEEDING HS       C
C      TIMEP(M,12).....MEAN RUN LENGTH                               C
C                                                                    C
C      M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR     C
C                                                                    C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE TABRUN

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      PARAMETER (NDZ=500)
      CHARACTER*30 COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/INPUT/H(2),HM01,TP1,FP1,GAM,SMAX,ALPHA1,SLOPE,IS,IDEEP
      COMMON/OUTPUT/COMMEN1,COMMEN2,COMMEN3,COMMEN4,COMMEN5
      COMMON/UPCROS/NZ(3),HRK(3,NDZ),TRK(3,NDZ),NK(3),LRN(3,NDZ)
      COMMON/TIMEPR/TIMEP(3,12)

C WRITE RUN LENGTH PARAMETERS TO (DATA) FILE RUNLTH OUT (UNIT=19)
      WRITE(19,*) COMMEN1
      WRITE(19,*) COMMEN2
      WRITE(19,*) COMMEN3
      WRITE(19,*) COMMEN4
      WRITE(19,*) COMMEN5
      WRITE(19,*)  ' '
      WRITE(19,*)  'RUN LENGTH PARAMETERS'
      WRITE(19,*)  ' '
      WRITE(19,*)  '                INCIDENT   SHOALED    REFRACTED'
      WRITE(19,*)  '   EVENT          WAVES     WAVES        WAVES  '
      WRITE(19,*)  '-----------------------------------------------'
      WRITE(19,10) H(1),H(2),H(2)
      WRITE(19,*)  '-----------------------------------------------'
      NA=NK(1)
      IF(NK(2).GT.NA)THEN
       NA=NK(2)
      ENDIF
      IF(NK(3).GT.NA)THEN
       NA=NK(3)
      ENDIF
      DO 200 I=1,NA
       WRITE(19,11) I,LRN(1,I),LRN(2,I),LRN(3,I)
```

```
 200  CONTINUE
      WRITE(19,*) ' '
      WRITE(19,12) TIMEP(1,12),TIMEP(2,12),TIMEP(3,12)
 10   FORMAT(' DEPTH (M)    ',F8.5,3X,F8.5,3X,F8.5)
 11   FORMAT(4X,I2,7X,I5,6X,I5,6X,I5)
 12   FORMAT('MEAN RUN LTH ',F8.5,3X,F8.5,3X,F8.5)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCC  SUBROUTINE 21  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C  FLFIGS                                                               C
C                                                                       C
C  OUPUTS QUANTITIES FOR PLOTTING                                       C
C                                                                       C
C        IN/OUT:                                                        C
C     NF...........NO. OF DISCRETE FREQUENCIES                          C
C     STMA(NF).....FREQUENCY SPECTRUM AT DEPTH 1 (M*M*S)                C
C     SUNI(NF).....SHOALED UNI-DIR FREQUENCY SPECTRUM AT                C
C                  DEPTH 2 (M*M*S)                                      C
C     SDIR(NF).....REFRACTED FREQUENCY SPECTRUM AT DEPTH 2 (M*M*S)      C
C     ND...........NO. OF DISCRETE DIRECTIONS                           C
C     D1(ND).......DIRECTIONAL ENERGY DISTRIBUTION FUNCTION             C
C                  AT DEPTH 1 (M*M/RAD)                                 C
C     D2(ND).......DIRECTIONAL ENERGY DISTRIBUTION FUNCTION             C
C                  AT DEPTH 2 (M*M/RAD)                                 C
C     S1(NF,ND)....INCIDENT DIRECTIONAL SPECTRUM AT DEPTH 1 (M*M*S/RAD)C
C     S2(NF,ND)....DIRECTIONAL SPECTRUM AT DEPTH 2 (M*M*S/RAD)          C
C     NP...........EVEN NO. OF DATA POINTS IN TIME SERIES               C
C     TS(M,N)......TIME SERIES FOR STMA, SUNI & SDIR (M)                C
C                                                                       C
C     M=1: INCIDENT   M=2: SHOALED UNI-DIR   M=3: REFRACTED DIR         C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      SUBROUTINE FLFIGS

C INITIALIZE & DIMENSION VARIABLES/COMMON STATEMENTS
      PARAMETER (NF=2001)
      PARAMETER (ND=181)
      PARAMETER (N=4000)
      COMMON/DISFRQ/DF,FQ(NF)
      COMMON/DISTIM/NP,DT,TIME(N)
```

```
      COMMON/DISDIR/DD,THETA(ND)
      COMMON/FQSPEC/STMA(NF),SUNI(NF),SDIR(NF),SEQU(NF)
      COMMON/DIREC1/S1(NF,ND),D1(ND)
      COMMON/DIREC2/S2(NF,ND),D2(ND)
      COMMON/SERIES/TS(3,N)

C WRITE TO (PLOT) FILES (UNITS 20-25)
      WRITE(20,10) (STMA(J),J=1,NF)
      WRITE(21,10) (SUNI(J),J=1,NF)
      WRITE(22,10) (SDIR(J),J=1,NF)
      WRITE(23,10) (SEQU(J),J=1,NF)
      WRITE(24,10) (D1(I),I=1,ND)
      WRITE(25,10) (D2(I),I=1,ND)

C WRITE DIRECTIONAL SPECTRA TO (PLOT) FILES FOR 3D PLOTTING
      DO 100 I=1,ND
       DO 200 J=1,NF
        WRITE(26,10) S1(J,I)
        WRITE(27,10) S2(J,I)
 200   CONTINUE
 100  CONTINUE

C WRITE TO (PLOT) FILES (UNITS 28-30)
      WRITE(28,10) (TS(1,K),K=1,NP)
      WRITE(29,10) (TS(2,K),K=1,NP)
      WRITE(30,10) (TS(3,K),K=1,NP)
 10   FORMAT(E17.9)

      RETURN
      END
```

Appendix B

ANALYZED RANDOM WAVE DATA: FIELD DATA EXAMPLE

This appendix contains the random wave data for two field data cases corresponding to Run 1 in Kobayashi and Wurjanto (1992) with the predominant incident wave direction $\alpha_p = 0°$ and $45°$ in (2.20). The following tables are included for each case:

1. Input Parameters.
2. Spectral Parameters.
3. Time Series Parameters.
4. Run Length Statistics.
5. Ranked Wave Heights and Breaker Heights for Incident Versus Shoaled Uni-Directional Frequency Spectra.
6. Ranked Wave Heights and Breaker Heights for Incident Versus Refracted Directional Frequency Spectra.

Also, the following figures are included for each case:

1. Refracted Frequency Spectrum Versus Shoaled Uni-Directional Frequency Spectrum at Depth 2.
2. Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1.

2. Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1.

3. Equivalent Uni-Directional Frequency Spectrum Versus Incident Frequency Spectrum at Depth 1.

4. Energy Distribution Function at Depth 2 Versus Energy Distribution Function at Depth 1.

5. Time Series Generated From Incident Frequency Spectrum at Depth 1.

6. Time Series Generated From Shoaled Uni-Directional Frequency Spectrum at Depth 2.

7. Time Series Generated From Refracted Frequency Spectrum at Depth 2.

8. Directional Spectrum at Depth 2 as a Function of Frequency and Direction.

9. Directional Spectrum at Depth 1 as a Function of Frequency and Direction.

Also included is the following comparison between the two cases:

10. Refracted Frequency Spectrum, $\alpha_p = 45°$, Versus Refracted Frequency Spectrum, $\alpha_p = 0°$.

Table B.1: INPUT PARAMETERS: $\alpha_p = 0°$

20.00000000		--> H1 (M)
4.14999962		--> H2 (M)
2.15999985	7.00000000	--> HM01 (M), TP1 (S)
1.00000000		--> GAMMA
1		--> IDEEP
10.00000000		--> SMAX
0.00000000		--> ALPHA1 (DEG)
0.03000000		--> SLOPE
13579		--> IS
2001		--> NO. OF FRQ.
181		--> NO. OF DIR.
0.00000000	1.42857075	--> FMIN (HZ), FMAX (HZ)
-89.99995420	89.99995420	--> THETAMIN (DEG), THETAMAX (DEG)

Table B.2: SPECTRAL PARAMETERS: $\alpha_p = 0°$

SPECTRAL PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
DEPTH (M)	20.00000	4.15000	4.15000
EP	0.79736	0.81352	0.78299
VU	0.41065	0.42180	0.38918
Qp	2.00051	2.09054	2.21653
ER	0.53947	0.55447	0.51610
HR	1.52586	1.56828	1.45976
HMO	2.16005	2.22010	2.06647
T1	5.40948	5.66035	5.74665
T2	5.00399	5.21538	5.35537
TP	7.00000	7.32985	7.17949
FP	0.14286	0.13643	0.13929
ALPHA	0.00000	0.00000	0.00000
KAPPA	0.42358	0.45513	0.46764

Table B.3: TIME SERIES PARAMETERS: $\alpha_p = 0°$

TIME SERIES PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
DEPTH (M)	20.00000	4.15000	4.15000
SD	0.00000	0.00000	0.00000
ER	0.53939	0.55439	0.51602
NZ	275.000	267.000	261.000
HB	1.32407	1.34429	1.25851
TB	5.09091	5.24345	5.36399
HV	1.47857	1.50866	1.40865
HS	2.07343	2.12555	1.97799
T3	6.24178	6.49121	6.48353
HT	2.55849	2.63555	2.43927
TT	6.26641	6.43732	6.42614
NK	26.000	24.000	25.000
M.R.L.	1.34615	1.29167	1.32000

Table B.4: RUN LENGTH STATISTICS: $\alpha_p = 0°$

EVENT	INCIDENT WAVES	SHOALED WAVES	REFRACTED WAVES
DEPTH (M)	20.00000	4.15000	4.15000
1	1	1	1
2	1	1	1
3	1	1	1
4	1	2	1
5	2	1	2
6	1	1	1
7	1	1	2
8	1	2	1
9	2	1	2
10	1	2	1
11	1	1	2
12	3	1	1
13	1	1	1
14	1	1	1
15	1	2	1
16	1	2	2
17	2	2	2
18	2	1	2
19	2	2	1
20	1	1	2
21	2	1	1
22	1	1	1
23	1	1	1
24	2	1	1
25	1	0	1
26	1	0	0
MEAN RUN LTH	1.34615	1.29167	1.32000

Table B.5: WAVE STATISTICS: INCIDENT VS. SHOALED: $\alpha_p = 0°$

	INC SPECTRUM		SHOALED SPECTRUM			
DEPTH(M)	20.00000		4.15000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	5.744	3.516	5.803	3.516	3.089	1
2	6.138	3.176	7.236	3.407	3.317	1
3	7.108	3.135	6.211	3.284	3.167	1
4	6.775	2.951	7.229	3.117	3.316	0
5	7.187	2.886	6.800	2.888	3.260	0
6	6.307	2.760	6.435	2.851	3.205	0
7	5.403	2.684	6.632	2.755	3.236	0
8	6.029	2.606	6.428	2.690	3.204	0
9	7.910	2.602	6.322	2.657	3.187	0
10	6.496	2.577	6.252	2.642	3.174	0
11	5.102	2.534	6.149	2.616	3.156	0
12	5.985	2.529	7.797	2.604	3.377	0
13	5.046	2.526	7.879	2.602	3.385	0
14	6.776	2.489	6.938	2.596	3.279	0
15	7.789	2.460	7.113	2.585	3.302	0
16	5.959	2.457	5.227	2.506	2.951	0
17	7.040	2.417	5.093	2.418	2.914	0
18	4.628	2.400	7.014	2.385	3.289	0
19	5.503	2.366	7.018	2.373	3.290	0
20	6.940	2.326	7.756	2.342	3.373	0
21	4.977	2.276	4.862	2.341	2.845	0
22	5.857	2.274	5.564	2.305	3.036	0
23	5.477	2.258	5.178	2.280	2.938	0
24	6.337	2.233	6.086	2.260	3.145	0
25	5.973	2.225	6.016	2.256	3.131	0

Table B.6: WAVE STATISTICS: INCIDENT VS. REFRACTED: $\alpha_p = 0°$

	INC SPECTRUM		REFRACTED SPECTRUM			
DEPTH(M)	20.00000		4.15000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	5.744	3.516	5.833	3.330	3.095	1
2	6.138	3.176	7.183	3.104	3.310	0
3	7.108	3.135	6.223	3.085	3.169	0
4	6.775	2.951	7.197	2.906	3.312	0
5	7.187	2.886	6.752	2.666	3.254	0
6	6.307	2.760	6.427	2.659	3.204	0
7	5.403	2.684	6.629	2.539	3.235	0
8	6.029	2.606	6.222	2.462	3.169	0
9	7.910	2.602	6.386	2.431	3.197	0
10	6.496	2.577	6.911	2.430	3.276	0
11	5.102	2.534	6.215	2.411	3.168	0
12	5.985	2.529	7.072	2.407	3.297	0
13	5.046	2.526	7.787	2.404	3.376	0
14	6.776	2.489	7.832	2.399	3.381	0
15	7.789	2.460	6.156	2.343	3.157	0
16	5.959	2.457	5.262	2.312	2.961	0
17	7.040	2.417	5.182	2.277	2.939	0
18	4.628	2.400	6.967	2.223	3.283	0
19	5.503	2.366	6.987	2.197	3.286	0
20	6.940	2.326	5.618	2.181	3.048	0
21	4.977	2.276	4.964	2.162	2.876	0
22	5.857	2.274	7.748	2.153	3.373	0
23	5.477	2.258	6.017	2.108	3.132	0
24	6.337	2.233	6.335	2.094	3.189	0
25	5.973	2.225	5.205	2.083	2.945	0

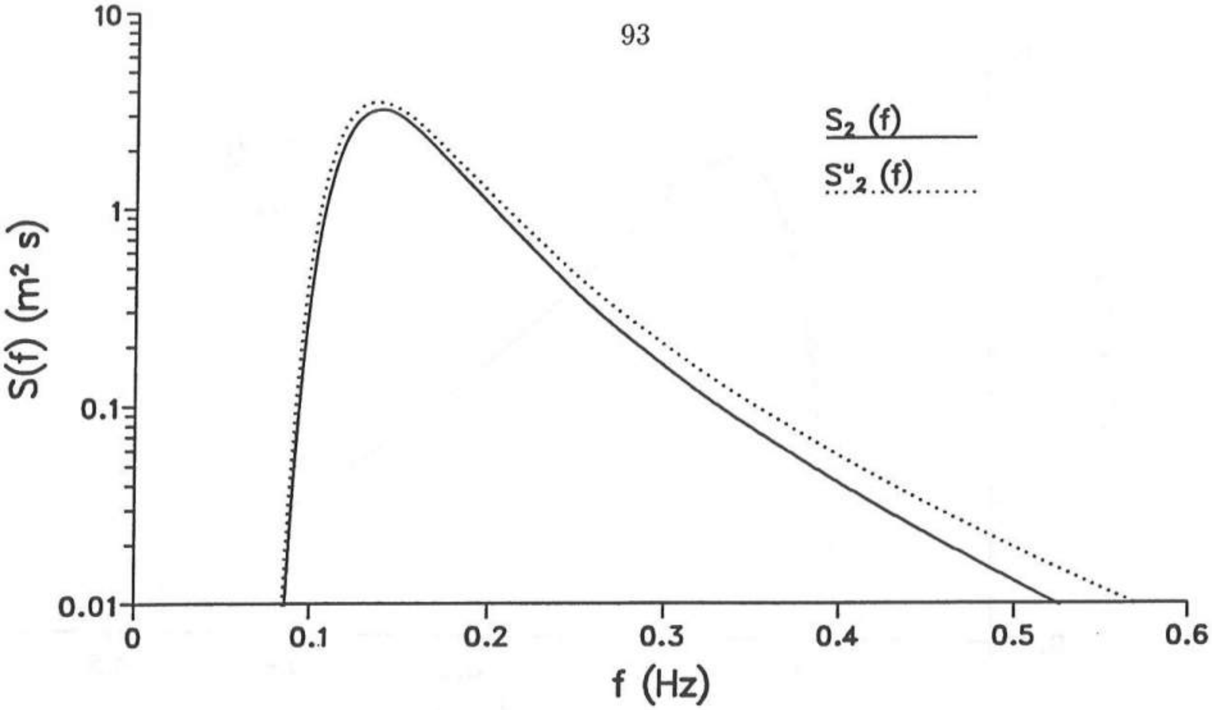

Figure B.1: Refracted Frequency Spectrum Versus Shoaled Uni-Directional Frequency Spectrum at Depth 2, $\alpha_p = 0°$

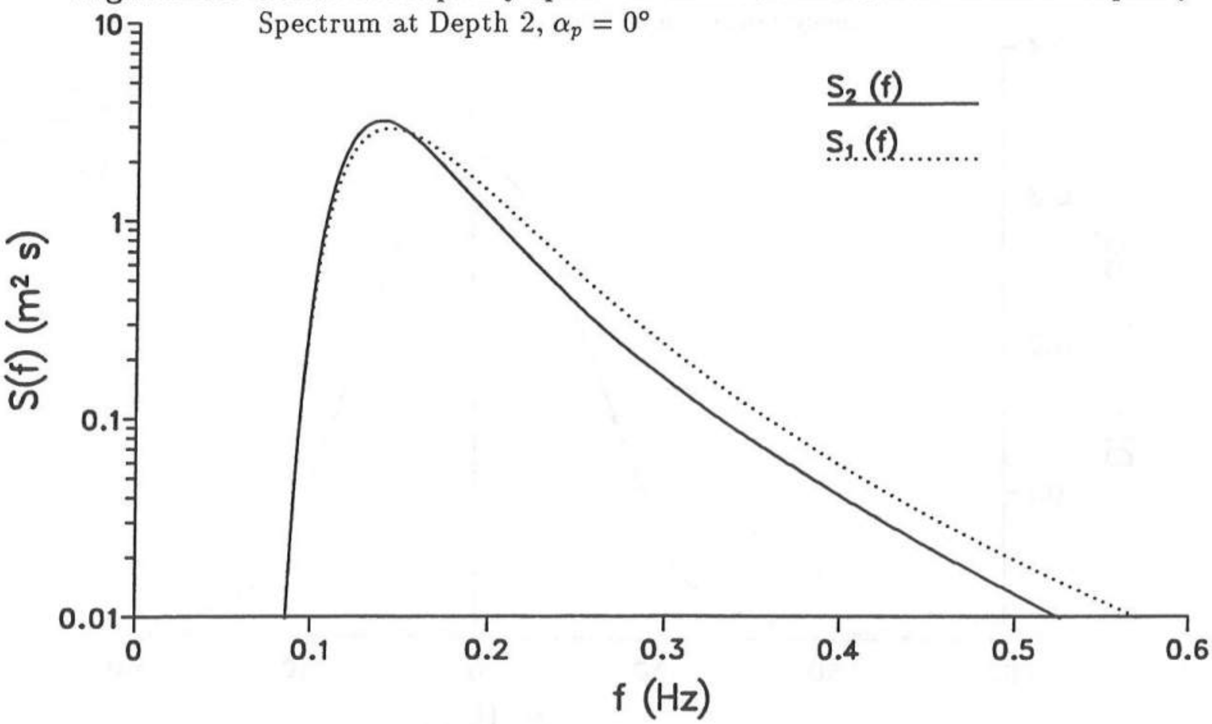

Figure B.2: Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1, $\alpha_p = 0°$

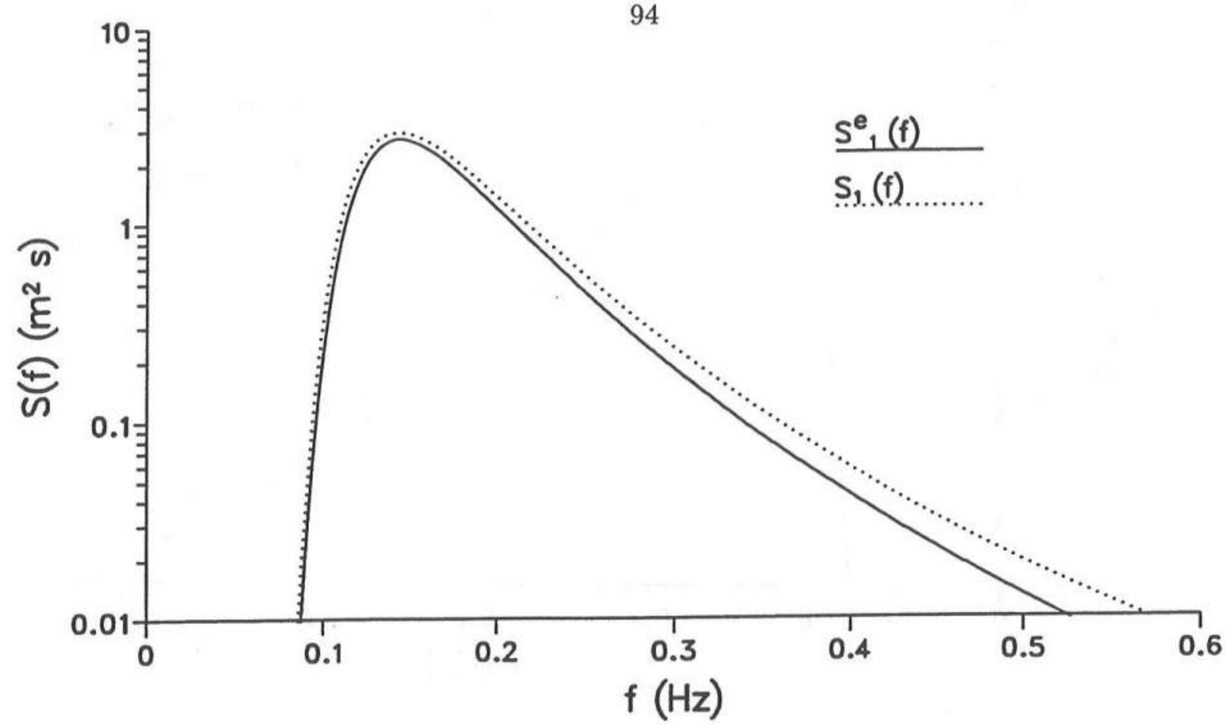

Figure B.3: Equivalent Uni-Directional Frequency Spectrum Versus Incident Frequency Spectrum at Depth 1, $\alpha_p = 0°$

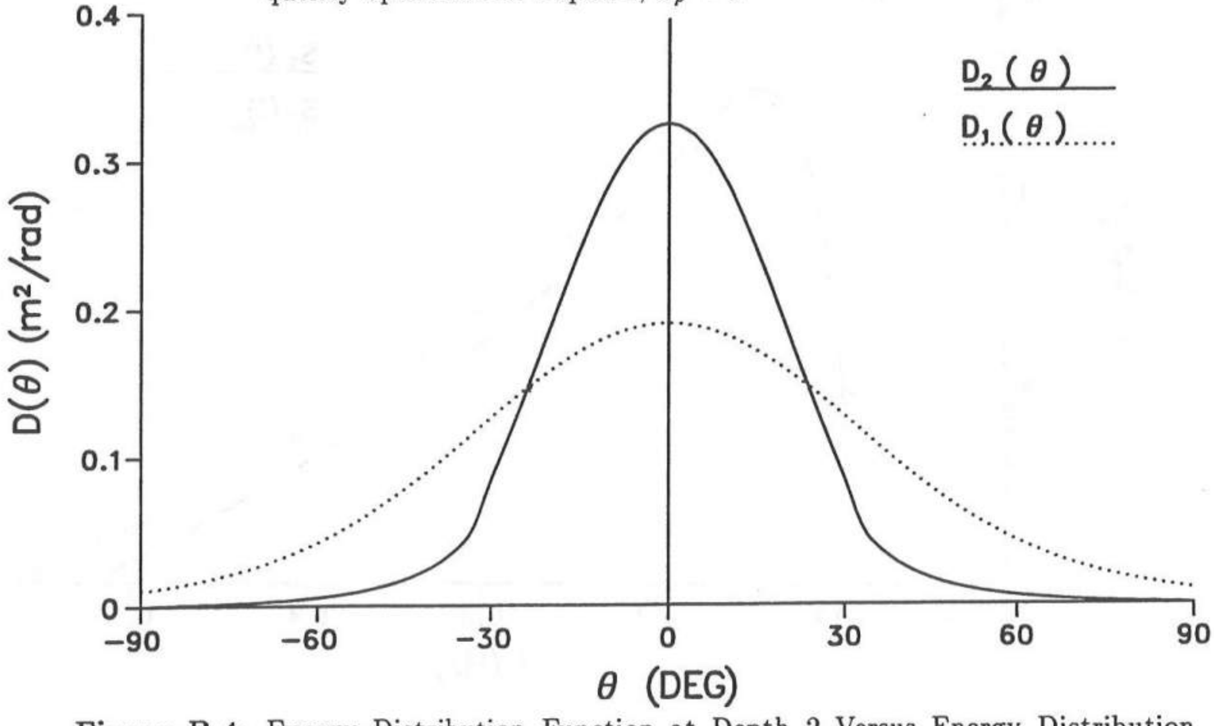

Figure B.4: Energy Distribution Function at Depth 2 Versus Energy Distribution Function at Depth 1, $\alpha_p = 0°$

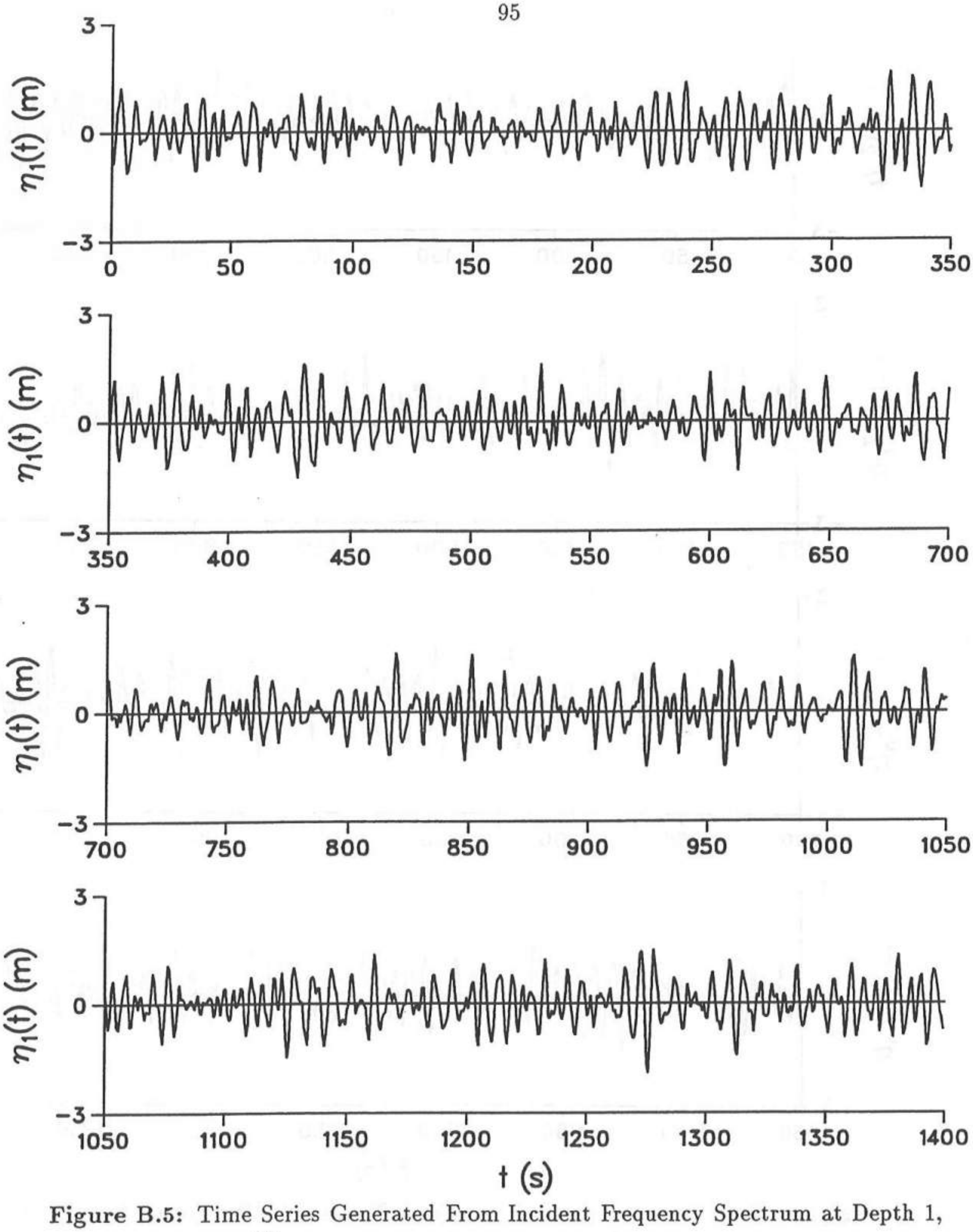

Figure B.5: Time Series Generated From Incident Frequency Spectrum at Depth 1, $\alpha_p = 0°$

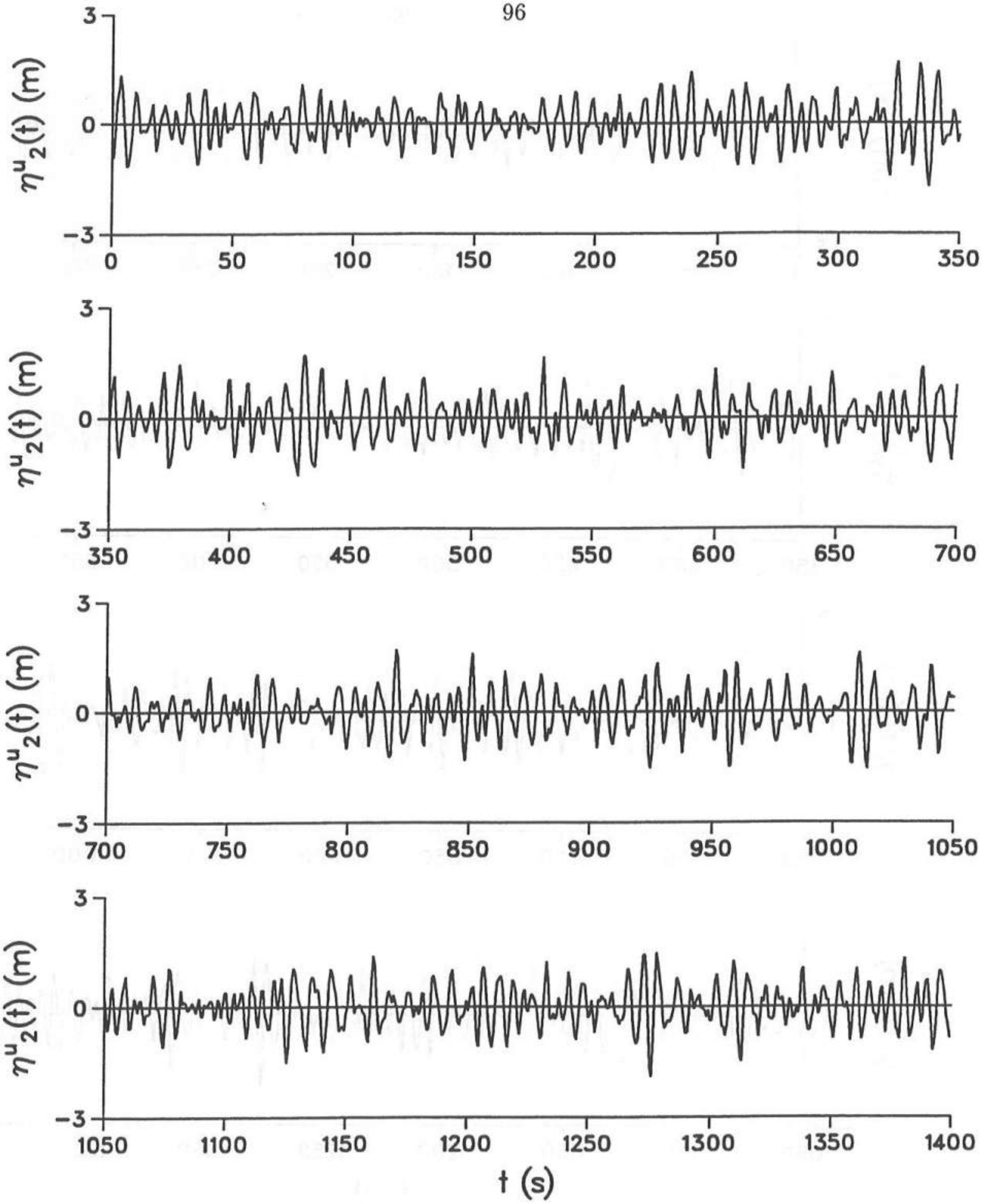

Figure B.6: Time Series Generated From Shoaled Uni-Directional Frequency Spectrum at Depth 2, $\alpha_p = 0°$

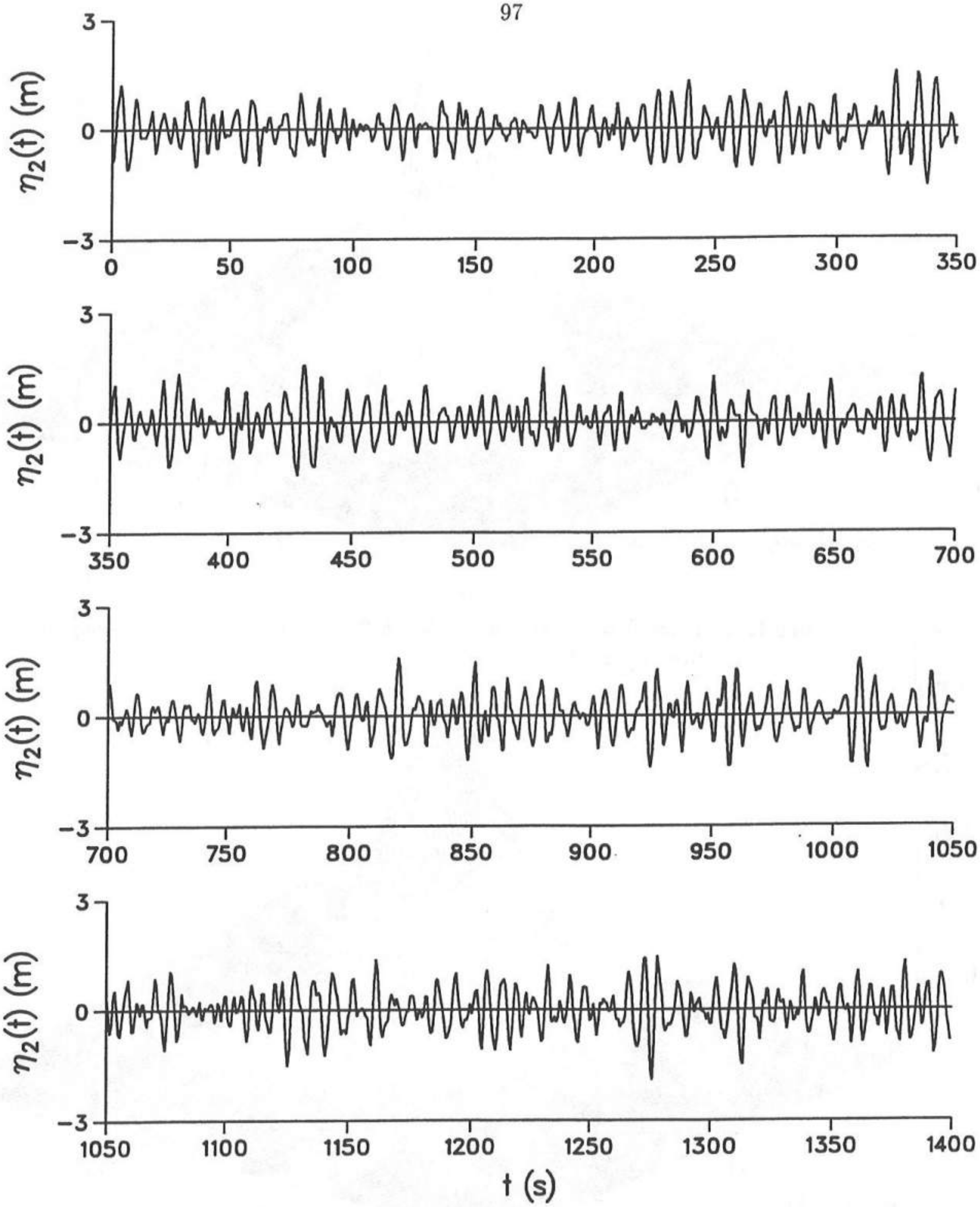

Figure B.7: Time Series Generated From Refracted Frequency Spectrum at Depth 2, $\alpha_p = 0°$

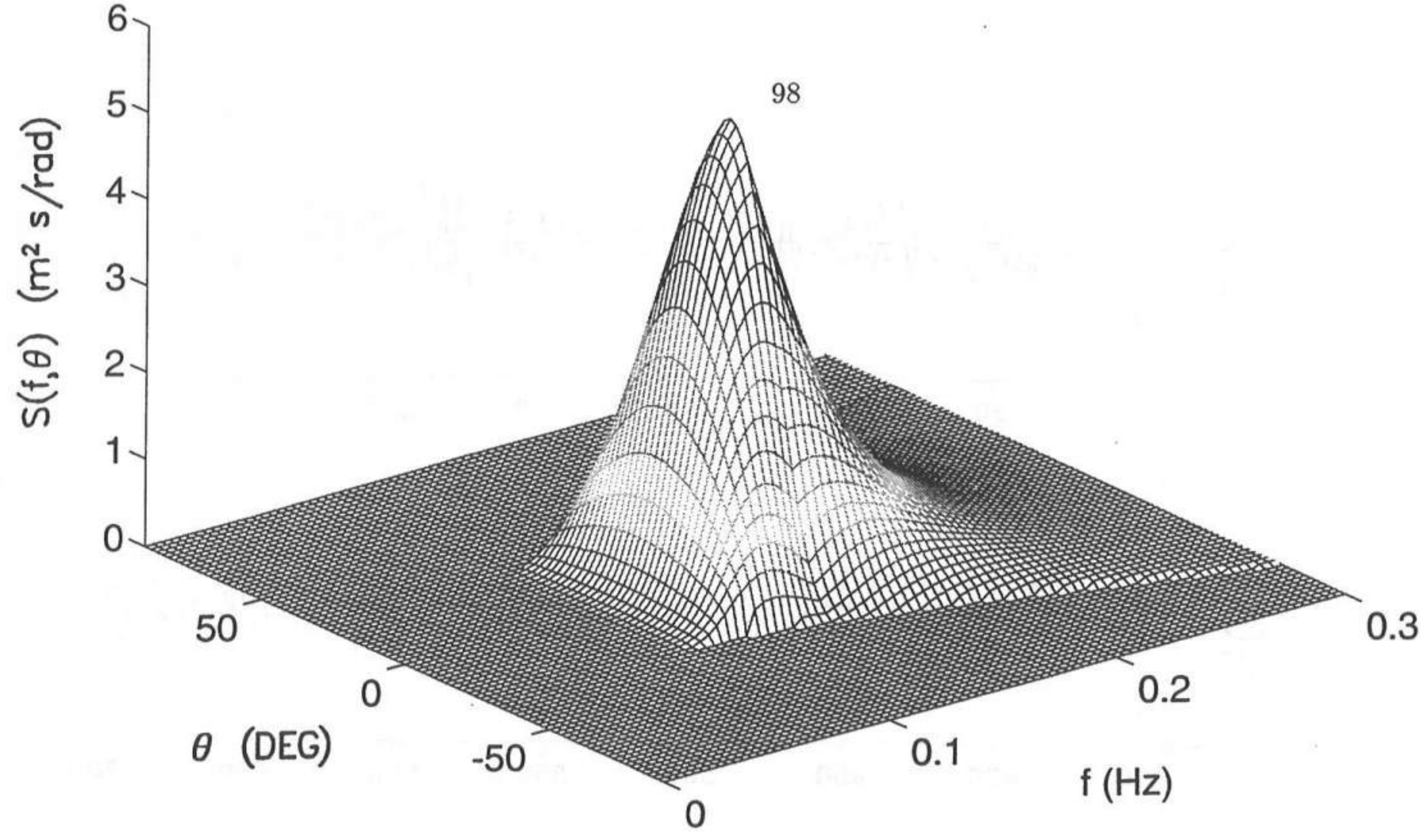

Figure B.8: Directional Spectrum at Depth 2 as a Function of Frequency and Direction, $\alpha_p = 0°$

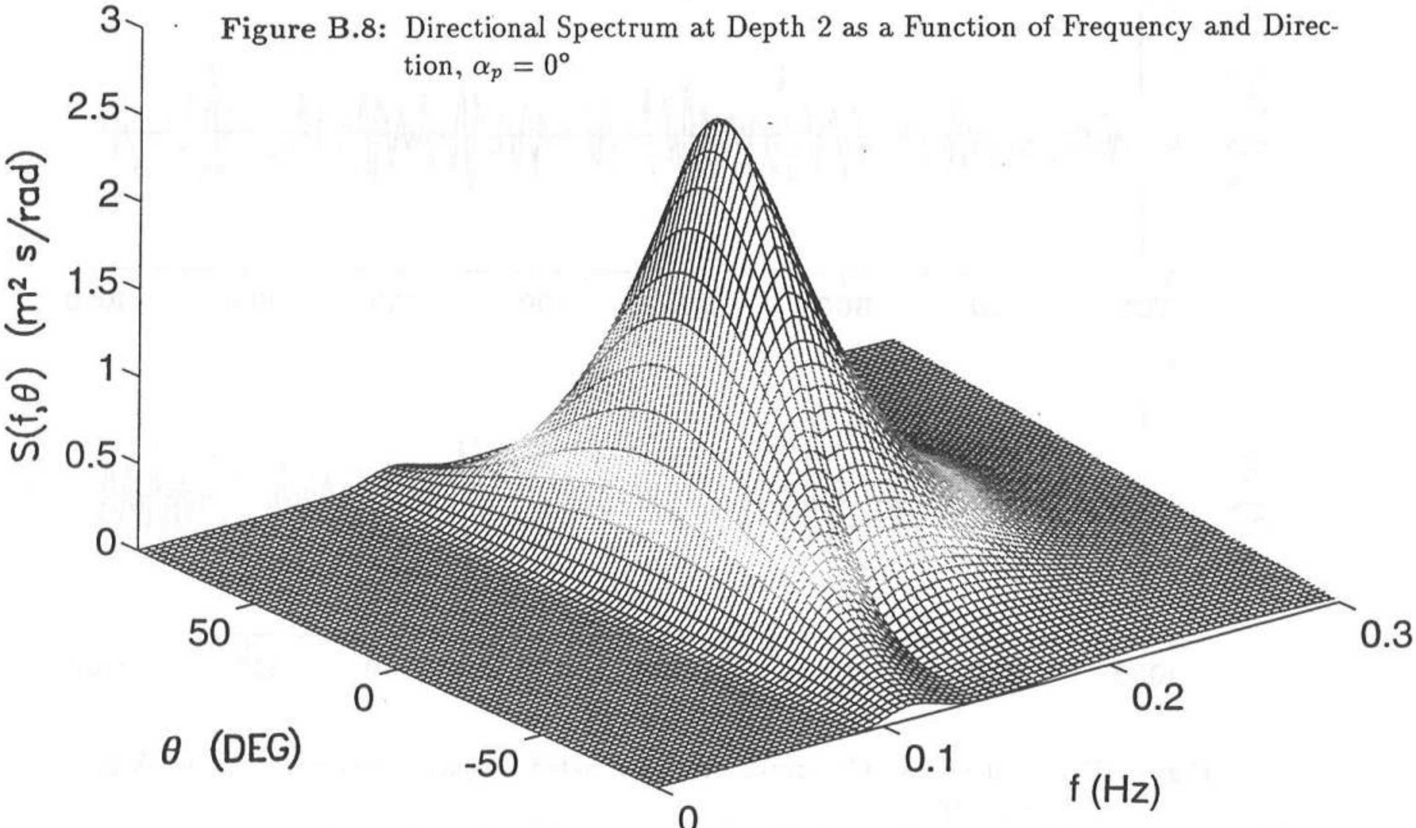

Figure B.9: Directional Spectrum at Depth 1 as a Function of Frequency and Direction, $\alpha_p = 0°$

Table B.7: INPUT PARAMETERS: $\alpha_p = 45°$

20.00000000		--> H1 (M)
4.14999962		--> H2 (M)
2.15999985	7.00000000	--> HM01 (M), TP1 (S)
1.00000000		--> GAMMA
1		--> IDEEP
10.00000000		--> SMAX
45.00000000		--> ALPHA1 (DEG)
0.03000000		--> SLOPE
13579		--> IS
2001		--> NO. OF FRQ.
181		--> NO. OF DIR.
0.00000000	1.42857075	--> FMIN (HZ), FMAX (HZ)
-89.99995420	89.99995420	--> THETAMIN (DEG), THETAMAX (DEG)

Table B.8: SPECTRAL PARAMETERS: $\alpha_p = 45°$

SPECTRAL PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
DEPTH (M)	20.00000	4.15000	4.15000
EP	0.79736	0.81352	0.79817
VU	0.41065	0.42180	0.40815
Qp	2.00051	2.09054	2.14144
ER	0.53947	0.55447	0.45305
HR	1.52586	1.56828	1.28141
HMO	2.16005	2.22010	1.81399
T1	5.40948	5.66035	5.66500
T2	5.00399	5.21538	5.24496
TP	7.00000	7.32985	7.21650
FP	0.14286	0.13643	0.13857
ALPHA	0.78540	0.00000	0.43633
KAPPA	0.42358	0.45513	0.46152

Table B.9: TIME SERIES PARAMETERS: $\alpha_p = 45°$

TIME SERIES PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
WATER DH (M)	20.00000	4.15000	4.15000
SD	0.00000	0.00000	0.00000
ER	0.53939	0.55439	0.45294
NZ	275.000	267.000	264.000
HB	1.32407	1.34429	1.10895
TB	5.09091	5.24345	5.30303
HV	1.47857	1.50866	1.23888
HS	2.07343	2.12555	1.73906
T3	6.24178	6.49121	6.47176
HT	2.55849	2.63555	2.14936
TT	6.26641	6.43732	6.41912
NK	26.000	24.000	24.000
M.R.L.	1.34615	1.29167	1.29167

Table B.10: RUN LENGTH STATISTICS: $\alpha_p = 45°$

EVENT	INCIDENT WAVES	SHOALED WAVES	REFRACTED WAVES
WATER DH (M)	20.00000	4.15000	4.15000
1	1	1	1
2	1	1	1
3	1	1	1
4	1	2	2
5	2	1	1
6	1	1	1
7	1	1	1
8	1	2	2
9	2	1	1
10	1	2	2
11	1	1	1
12	3	1	1
13	1	1	1
14	1	1	1
15	1	2	2
16	1	2	2
17	2	2	2
18	2	1	1
19	2	2	2
20	1	1	1
21	2	1	1
22	1	1	1
23	1	1	1
24	2	1	1
25	1	0	0
26	1	0	0
MEAN RUN LTH	1.34615	1.29167	1.29167

Table B.11: WAVE STATISTICS: INCIDENT VS. SHOALED: $\alpha_p = 45°$

	INC SPECTRUM		SHOALED SPECTRUM			
DEPTH(M)	20.00000		4.15000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	5.744	3.516	5.803	3.516	3.089	1
2	6.138	3.176	7.236	3.407	3.317	1
3	7.108	3.135	6.211	3.284	3.167	1
4	6.775	2.951	7.229	3.117	3.316	0
5	7.187	2.886	6.800	2.888	3.260	0
6	6.307	2.760	6.435	2.851	3.205	0
7	5.403	2.684	6.632	2.755	3.236	0
8	6.029	2.606	6.428	2.690	3.204	0
9	7.910	2.602	6.322	2.657	3.187	0
10	6.496	2.577	6.252	2.642	3.174	0
11	5.102	2.534	6.149	2.616	3.156	0
12	5.985	2.529	7.797	2.604	3.377	0
13	5.046	2.526	7.879	2.602	3.385	0
14	6.776	2.489	6.938	2.596	3.279	0
15	7.789	2.460	7.113	2.585	3.302	0
16	5.959	2.457	5.227	2.506	2.951	0
17	7.040	2.417	5.093	2.418	2.914	0
18	4.628	2.400	7.014	2.385	3.289	0
19	5.503	2.366	7.018	2.373	3.290	0
20	6.940	2.326	7.756	2.342	3.373	0
21	4.977	2.276	4.862	2.341	2.845	0
22	5.857	2.274	5.564	2.305	3.036	0
23	5.477	2.258	5.178	2.280	2.938	0
24	6.337	2.233	6.086	2.260	3.145	0
25	5.973	2.225	6.016	2.256	3.131	0

Table B.12: WAVE STATISTICS: INCIDENT VS. REFRACTED: $\alpha_p = 45°$

	INC SPECTRUM		REFRACTED SPECTRUM			
DEPTH(M)	20.00000		4.15000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	5.744	3.516	5.815	2.907	3.091	0
2	6.138	3.176	7.200	2.745	3.312	0
3	7.108	3.135	6.207	2.697	3.167	0
4	6.775	2.951	7.209	2.529	3.313	0
5	7.187	2.886	6.775	2.367	3.257	0
6	6.307	2.760	6.427	2.334	3.204	0
7	5.403	2.684	6.614	2.236	3.233	0
8	6.029	2.606	6.348	2.166	3.191	0
9	7.910	2.602	6.226	2.163	3.170	0
10	6.496	2.577	6.233	2.147	3.171	0
11	5.102	2.534	6.906	2.117	3.275	0
12	5.985	2.529	7.857	2.116	3.383	0
13	5.046	2.526	7.785	2.116	3.376	0
14	6.776	2.489	7.089	2.108	3.299	0
15	7.789	2.460	6.125	2.108	3.152	0
16	5.959	2.457	5.230	2.051	2.952	0
17	7.040	2.417	5.135	2.003	2.926	0
18	4.628	2.400	6.987	1.947	3.286	0
19	5.503	2.366	6.996	1.927	3.287	0
20	6.940	2.326	5.593	1.919	3.043	0
21	4.977	2.276	4.878	1.916	2.849	0
22	5.857	2.274	7.750	1.895	3.373	0
23	5.477	2.258	5.162	1.851	2.934	0
24	6.337	2.233	6.012	1.850	3.131	0
25	5.973	2.225	6.325	1.839	3.187	0

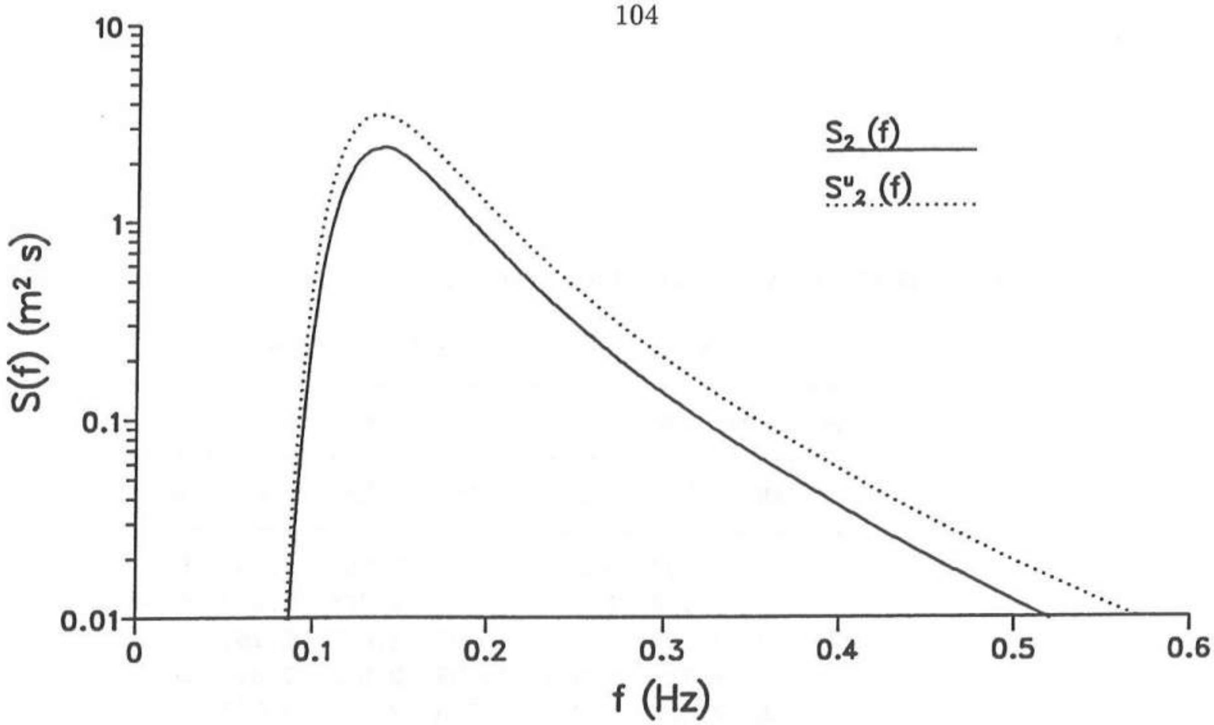

Figure B.10: Refracted Frequency Spectrum Versus Shoaled Uni-Directional Frequency Spectrum at Depth 2, $\alpha_p = 45°$

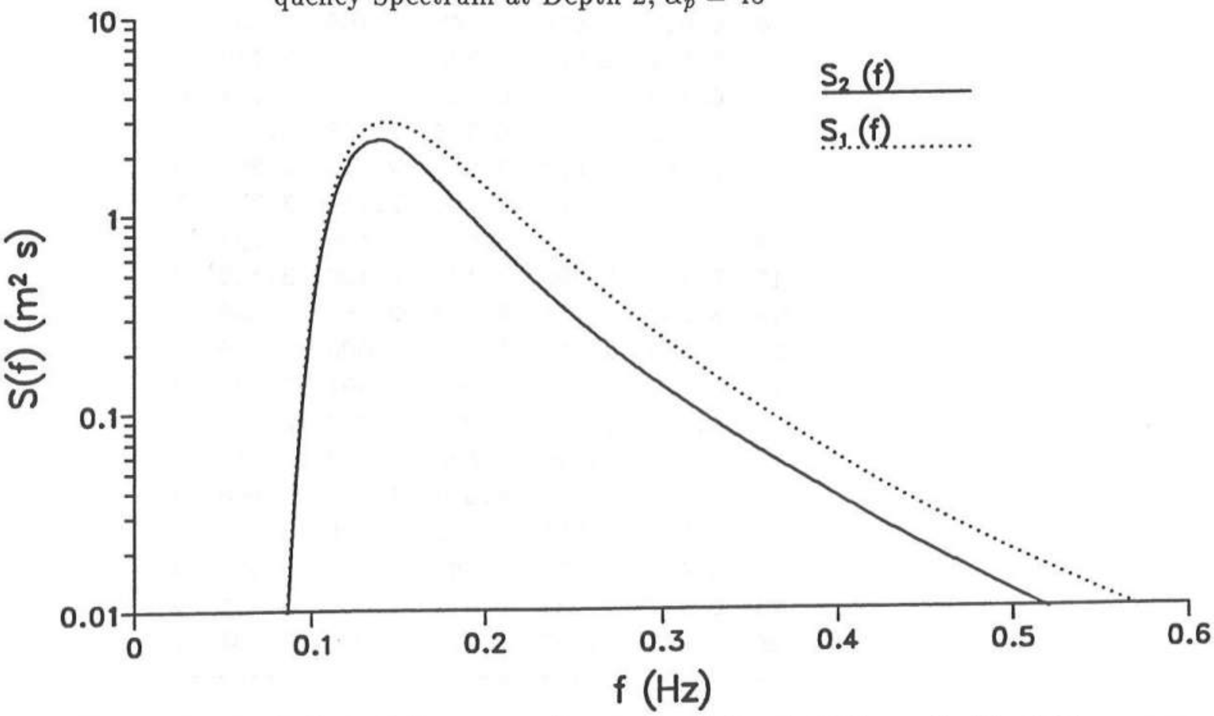

Figure B.11: Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1, $\alpha_p = 45°$

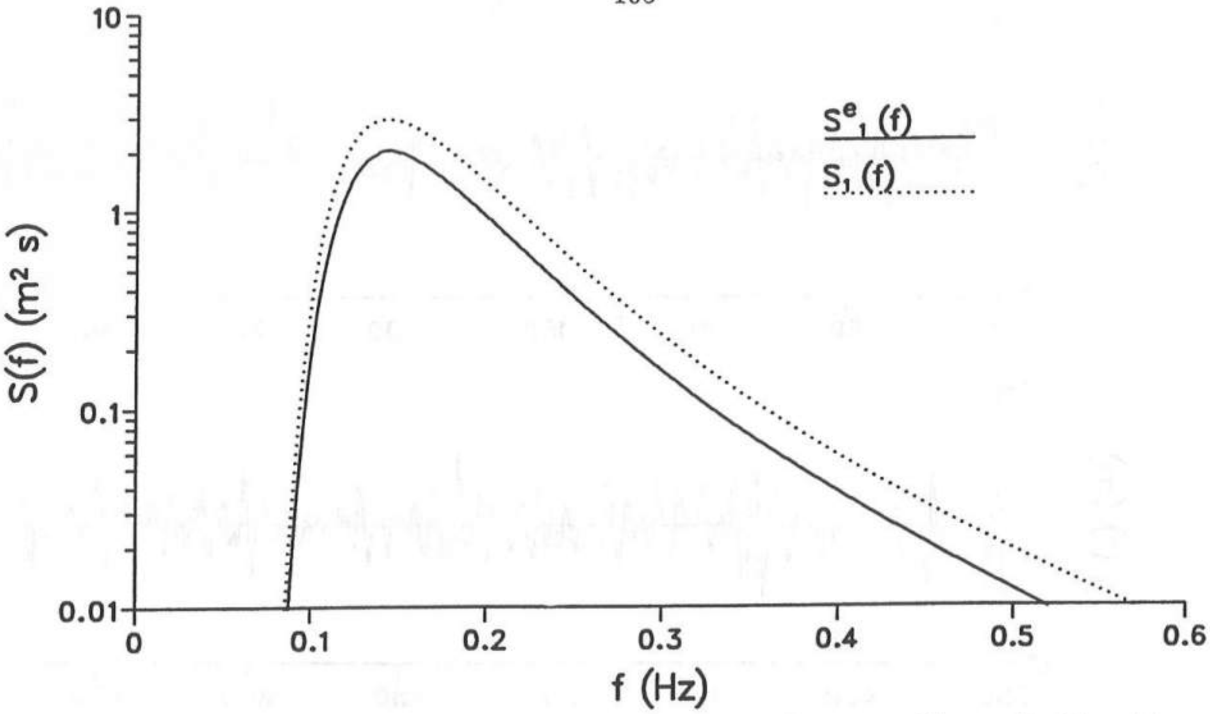

Figure B.12: Equivalent Uni-Directional Frequency Spectrum Versus Incident Frequency Spectrum at Depth 1, $\alpha_p = 45°$

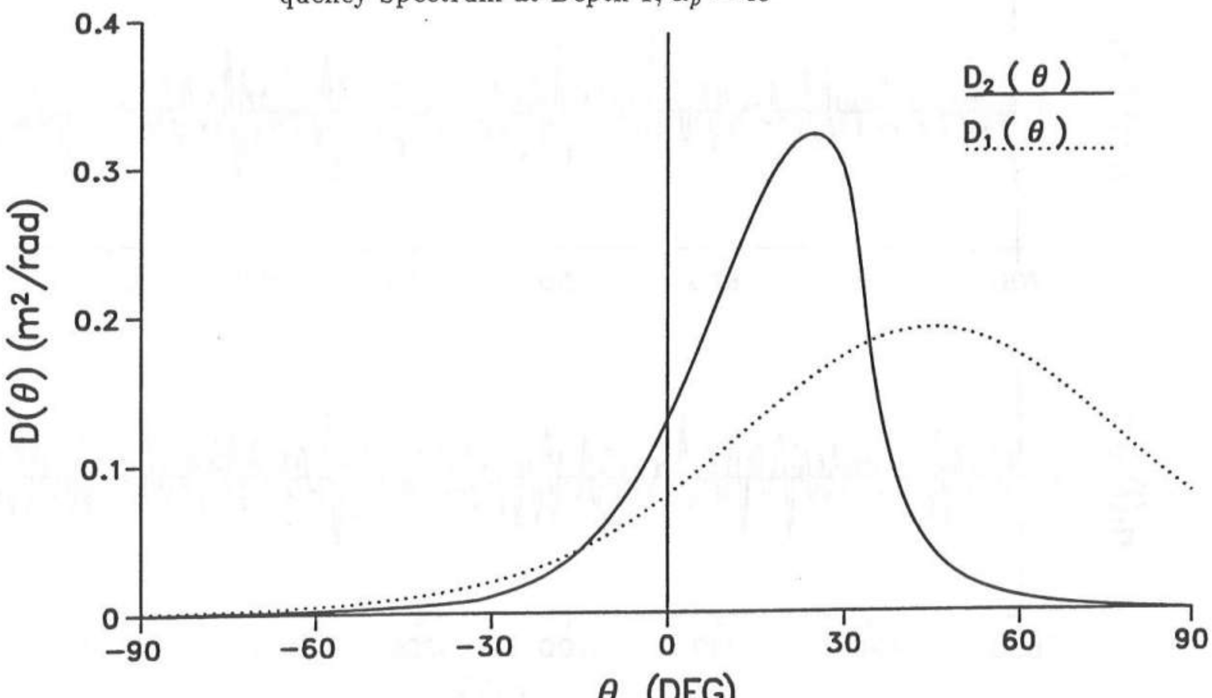

Figure B.13: Energy Distribution Function at Depth 2 Versus Energy Distribution Function at Depth 1, $\alpha_p = 45°$

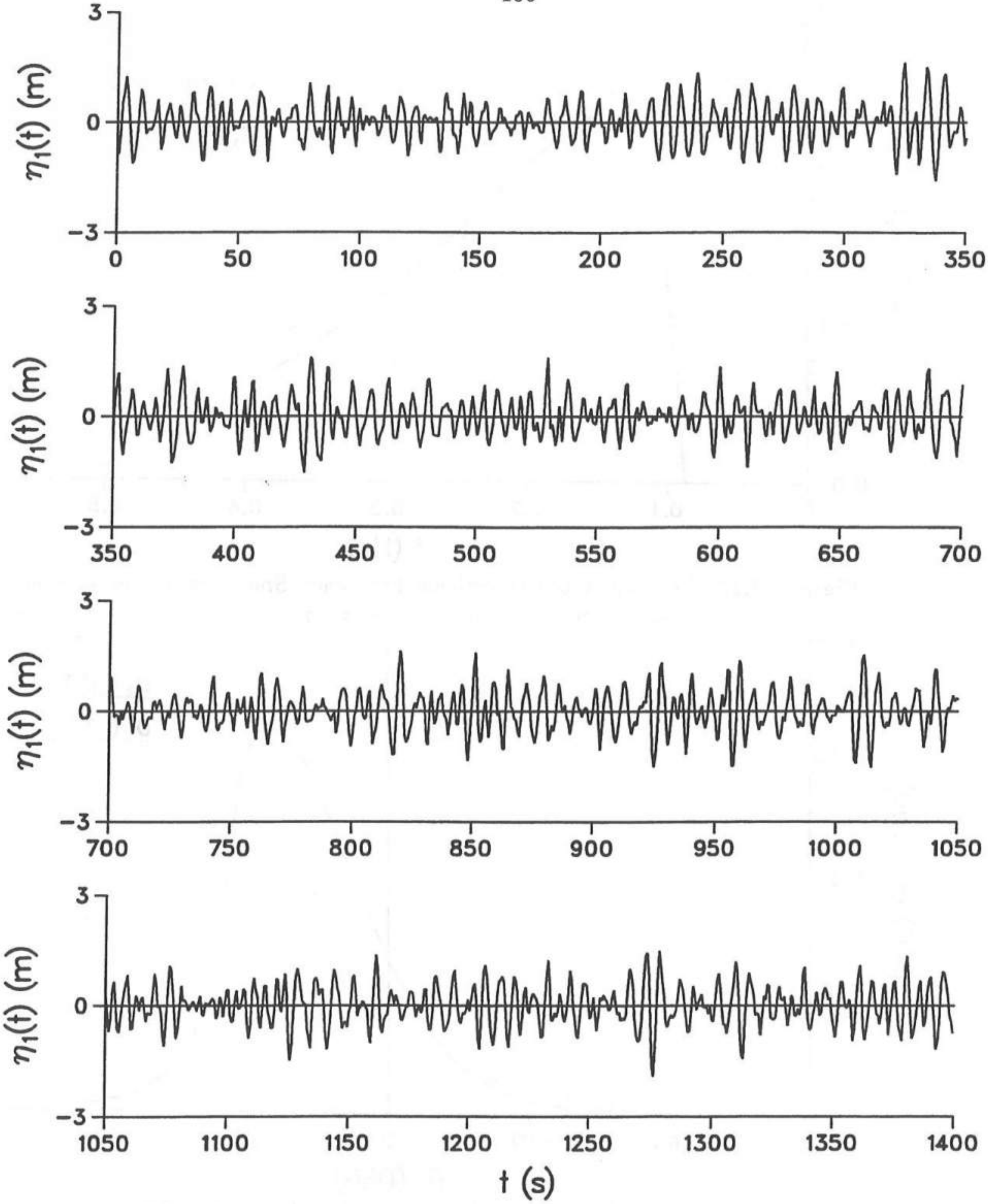

Figure B.14: Time Series Generated From Frequency Spectrum at Depth 1, $\alpha_p = 45°$

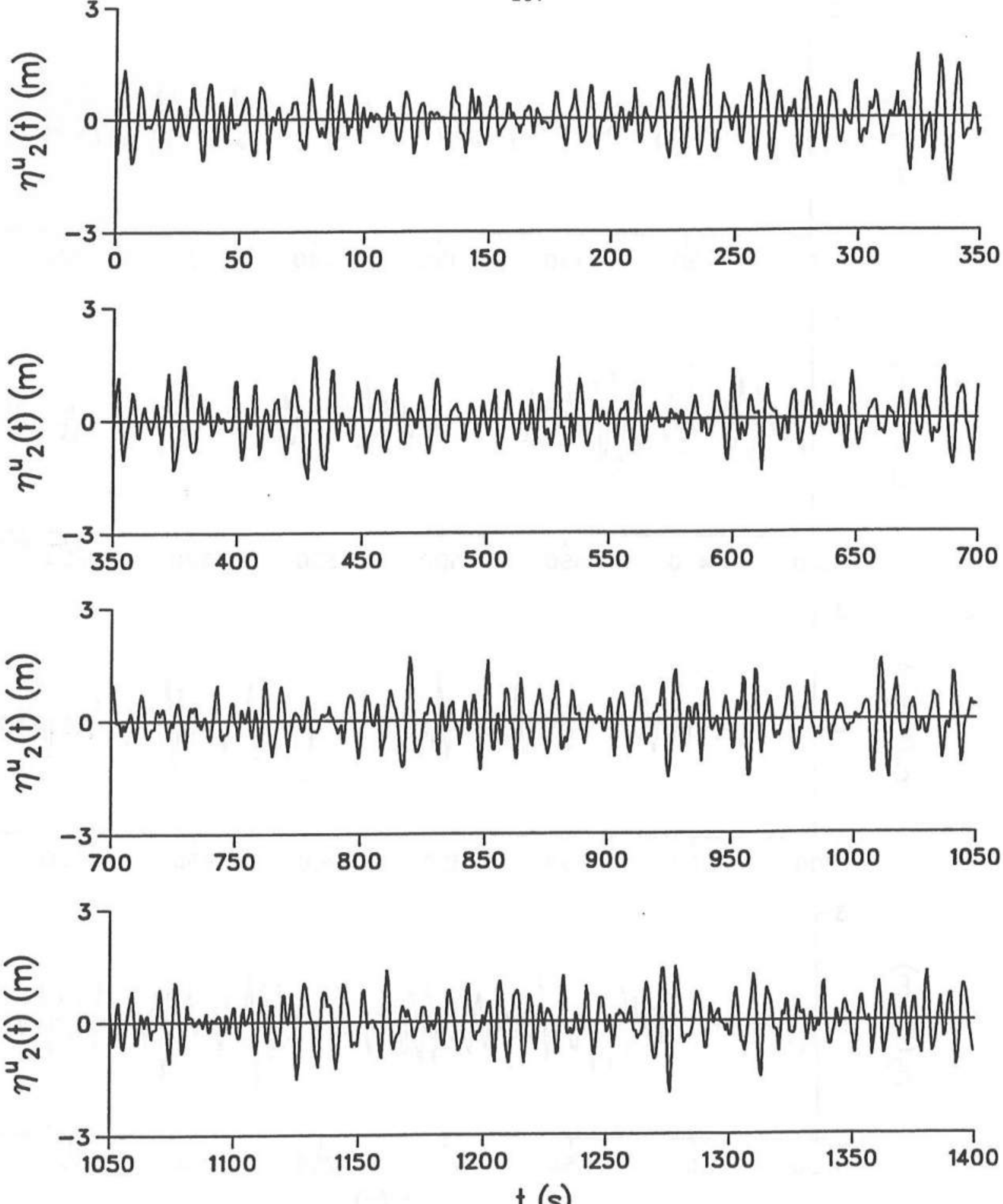

Figure B.15: Time Series Generated From Shoaled Uni-Directional Frequency Spectrum at Depth 2, $\alpha_p = 45°$

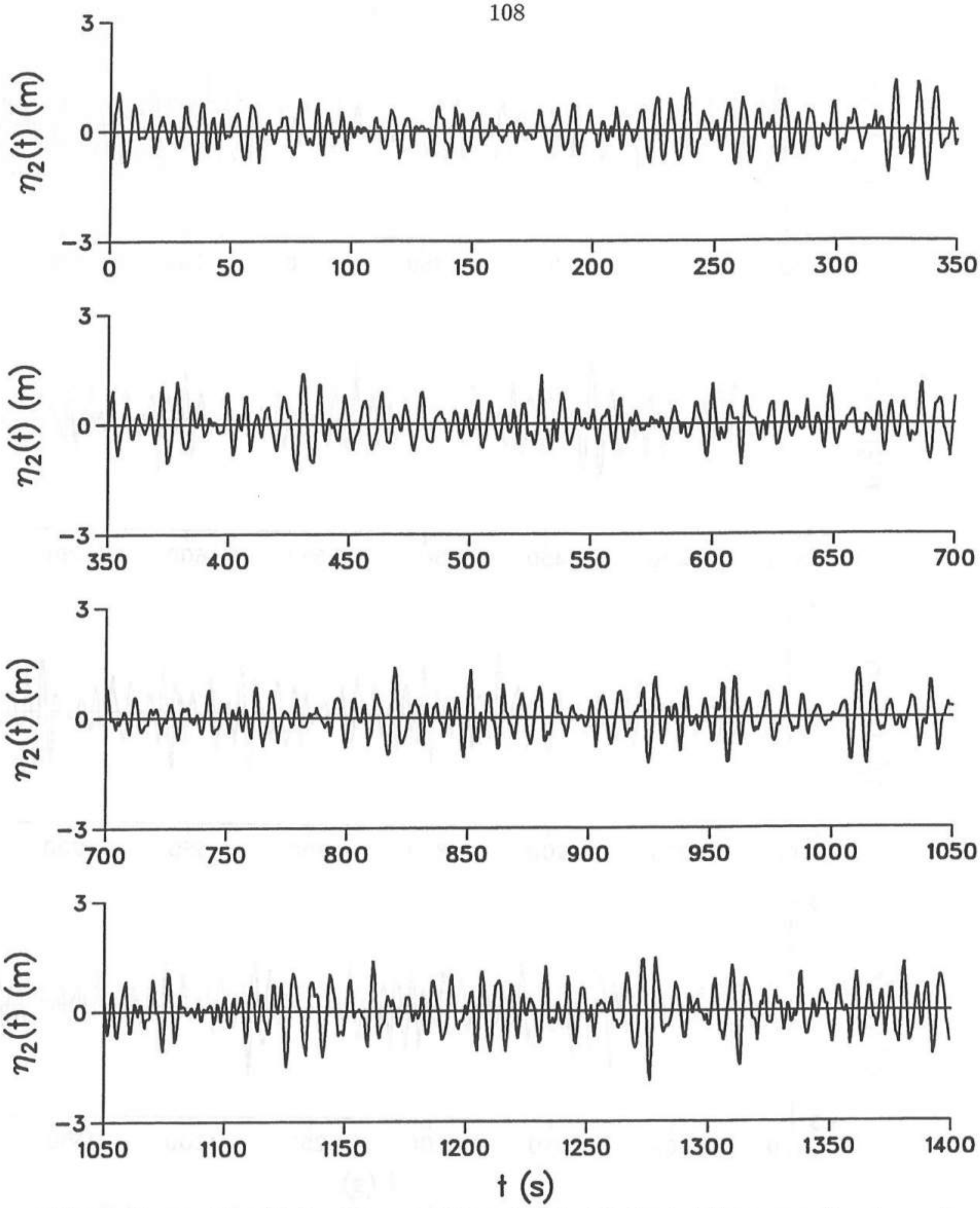

Figure B.16: Time Series Generated From Incident Refracted Frequency Spectrum at Depth 2, $\alpha_p = 45°$

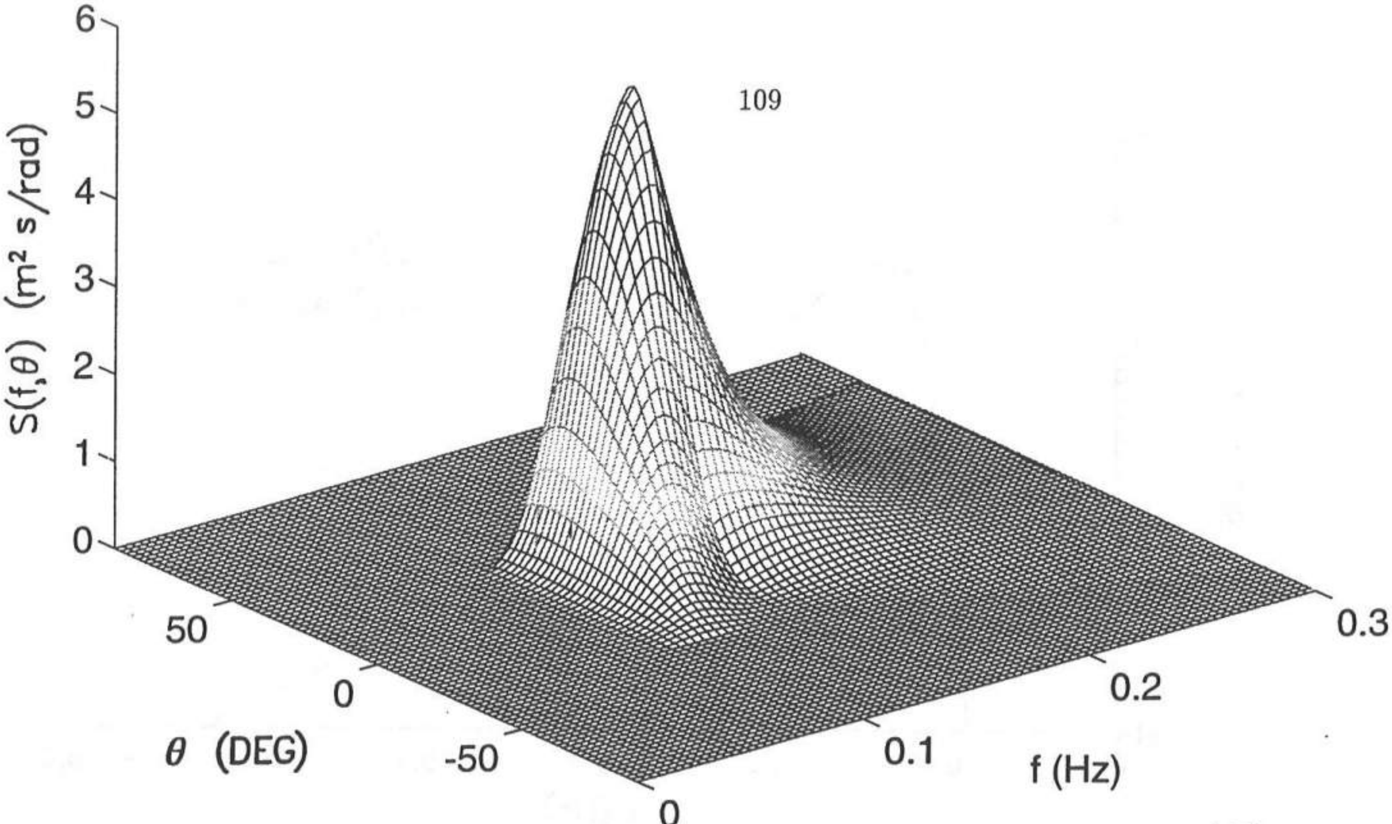

Figure B.17: Directional Spectrum at Depth 2 as a Function of Frequency and Direction, $\alpha_p = 45°$

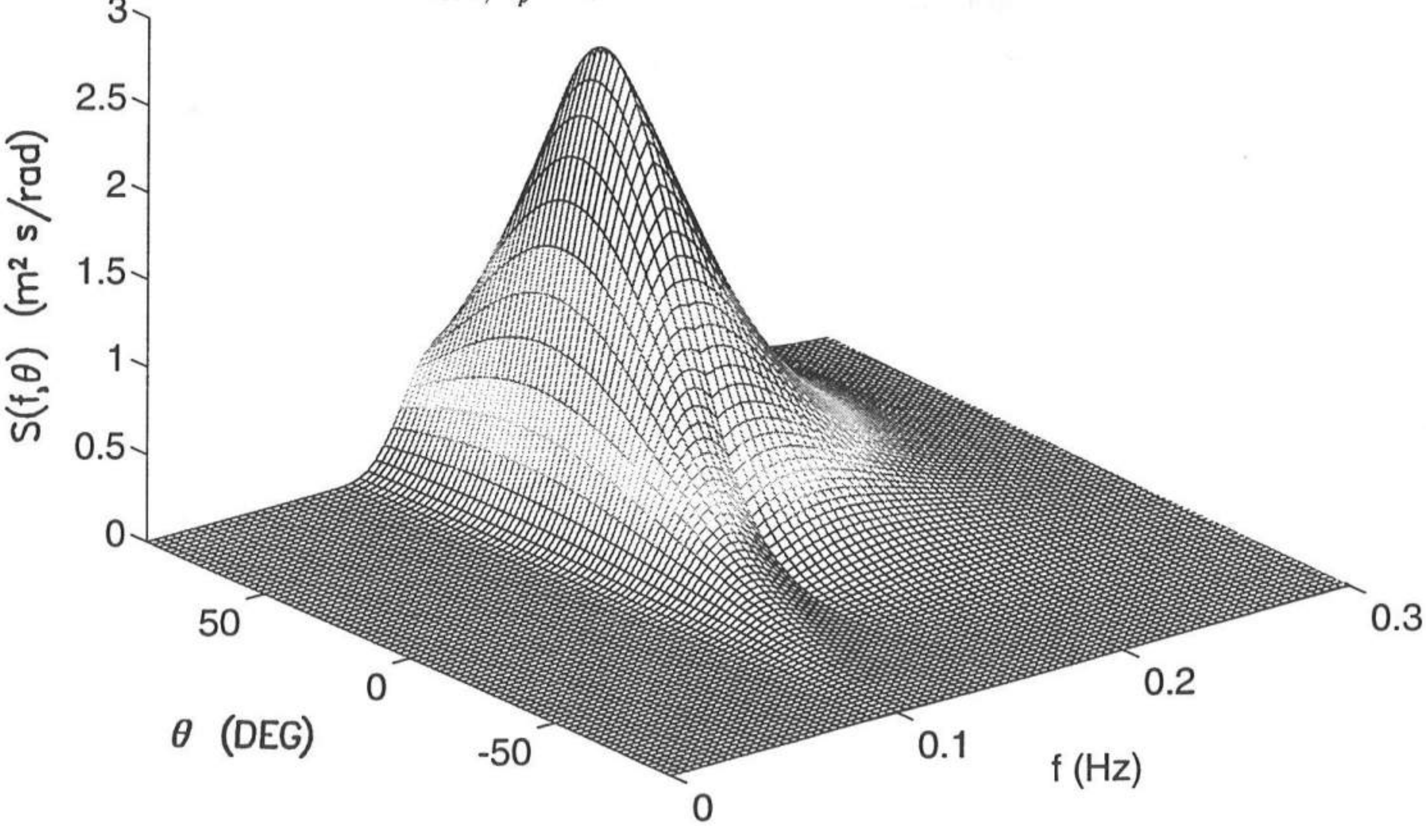

Figure B.18: Directional Spectrum at Depth 1 as a Function of Frequency and Direction, $\alpha_p = 45°$

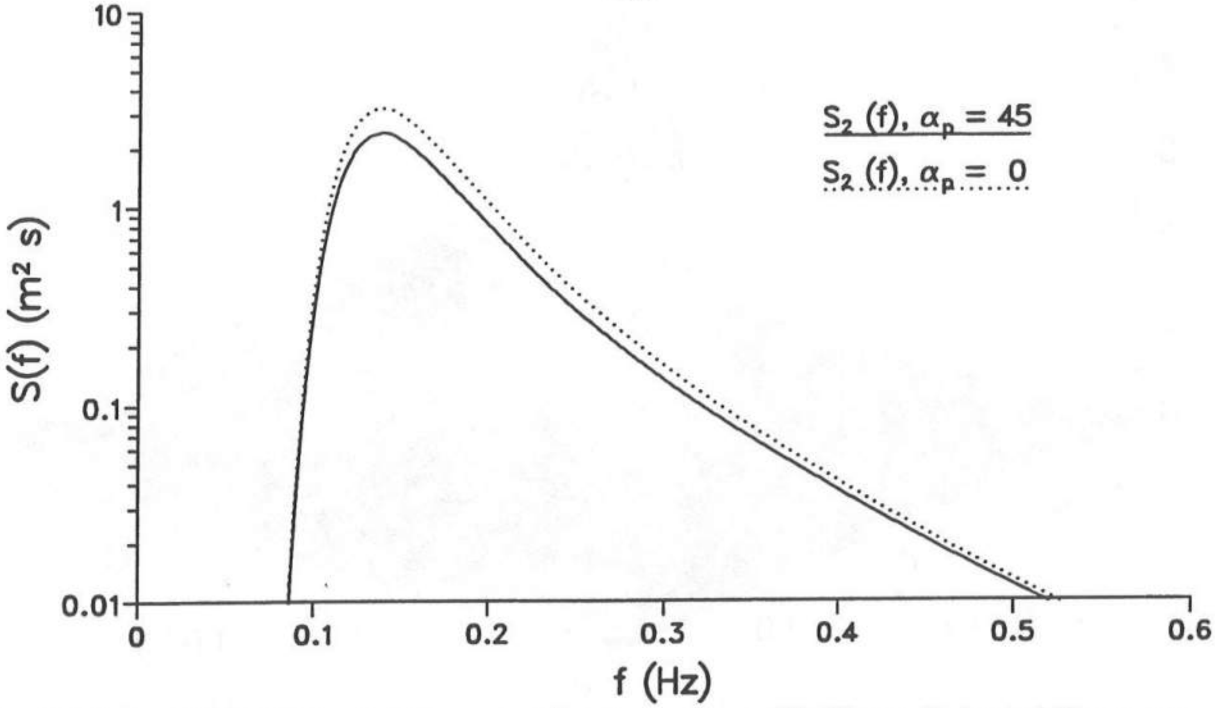

Figure B.19: Refracted Frequency Spectrum, $\alpha_p = 45°$, Versus Refracted Frequency Spectrum, $\alpha_p = 0°$

Appendix C

ANALYZED RANDOM WAVE DATA: LABORATORY EXAMPLE

This appendix contains the random wave data for one laboratory case corresponding to Run SN7 in Poff and Kobayashi (1993). The following tables are included:

1. Input Parameters.
2. Spectral Parameters.
3. Time Series Parameters.
4. Run Length Statistics.
5. Ranked Wave Heights and Breaker Heights for Incident Versus Shoaled Uni-Directional Frequency Spectra.
6. Ranked Wave Heights and Breaker Heights for Incident Versus Refracted Directional Frequency Spectra.

Also, the following figures are included for this case:

1. Refracted Frequency Spectrum Versus Shoaled Uni-Directional Frequency Spectrum at Depth 2.
2. Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1.

3. Equivalent Uni-Directional Frequency Spectrum Versus Incident Frequency Spectrum at Depth 1.

4. Energy Distribution Function at Depth 2 Versus Energy Distribution Function at Depth 1.

5. Time Series Generated From Incident Frequency Spectrum at Depth 1.

6. Time Series Generated From Shoaled Uni-Directional Frequency Spectrum at Depth 2.

7. Time Series Generated From Refracted Frequency Spectrum at Depth 2.

8. Directional Spectrum at Depth 2 as a Function of Frequency and Direction.

9. Directional Spectrum at Depth 1 as a Function of Frequency and Direction.

Table C.1: INPUT PARAMETERS

0.42000002		--> H1 (M)
0.30000001		--> H2 (M)
0.12000000	2.00000000	--> HMO1 (M), TP1 (S)
20.00000000		--> GAMMA
0		--> IDEEP
10.00000000		--> SMAX
0.00000000		--> ALPHA1 (DEG)
0.04250000		--> SLOPE
13579		--> IS
2001		--> NO. OF FRQ.
181		--> NO. OF DIR.
0.00000000	5.00000000	--> FMIN (HZ), FMAX (HZ)
-89.99995420	89.99995420	--> THETAMIN (DEG), THETAMAX (DEG)

Table C.2: SPECTRAL PARAMETERS

SPECTRAL PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
DEPTH (M)	0.42000	0.30000	0.30000
EP	0.82695	0.82575	0.79121
VU	0.41175	0.39998	0.35735
Qp	5.89288	6.13025	6.47609
ER	0.02997	0.03124	0.03021
HR	0.08477	0.08836	0.08545
HMO	0.12000	0.12508	0.12096
T1	1.66130	1.68688	1.72719
T2	1.53617	1.56624	1.62646
TP	2.00000	1.99005	1.99005
FP	0.50000	0.50250	0.50250
ALPHA	0.00000	0.00000	0.00000
KAPPA	0.70083	0.71635	0.73282

Table C.3: TIME SERIES PARAMETERS

TIME SERIES PARAMETERS	INCIDENT SPECTRUM	SHOALED SPECTRUM	REFRACTED SPECTRUM
DEPTH (M)	0.42000	0.30000	0.30000
SD	0.00000	0.00000	0.00000
ER	0.02997	0.03124	0.03021
NZ	254.000	253.000	241.000
HB	0.07425	0.07658	0.07566
TB	1.57480	1.58103	1.65975
HV	0.08289	0.08588	0.08400
HS	0.11550	0.12002	0.11627
T3	1.89689	1.89982	1.90405
HT	0.13959	0.14501	0.13993
TT	1.85849	1.87796	1.87948
NK	19.000	19.000	19.000
M.R.L.	1.73684	1.78947	1.78947

Table C.4: RUN LENGTH STATISTICS

EVENT	INCIDENT WAVES	SHOALED WAVES	REFRACTED WAVES
DEPTH (M)	0.42000	0.30000	0.30000
1	2	2	2
2	2	1	2
3	1	1	1
4	2	3	3
5	1	1	1
6	2	2	2
7	2	2	2
8	1	1	1
9	1	1	1
10	6	6	6
11	1	1	1
12	2	2	2
13	2	2	2
14	1	1	1
15	1	1	1
16	2	2	1
17	2	2	2
18	1	1	1
19	1	2	2
MEAN RUN LTH	1.73684	1.78947	1.78947

Table C.5: WAVE STATISTICS: INCIDENT VS. SHOALED

	INC SPECTRUM		SHOALED SPECTRUM			
DEPTH(M)	0.42000		0.30000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	1.723	0.182	1.731	0.190	0.246	0
2	1.704	0.160	1.711	0.166	0.245	0
3	1.810	0.158	1.815	0.165	0.250	0
4	1.930	0.154	1.932	0.159	0.254	0
5	1.899	0.149	1.903	0.155	0.253	0
6	1.928	0.149	1.989	0.153	0.256	0
7	1.991	0.146	1.924	0.152	0.254	0
8	1.847	0.146	1.855	0.151	0.251	0
9	1.842	0.142	1.958	0.146	0.255	0
10	1.858	0.140	1.860	0.145	0.251	0
11	1.957	0.139	1.849	0.144	0.251	0
12	1.712	0.138	2.035	0.143	0.258	0
13	2.040	0.137	1.723	0.141	0.245	0
14	1.833	0.135	1.830	0.140	0.250	0
15	2.148	0.135	2.143	0.139	0.261	0
16	1.813	0.134	1.828	0.139	0.250	0
17	1.852	0.132	1.852	0.139	0.251	0
18	1.965	0.129	1.966	0.135	0.255	0
19	1.480	0.128	1.744	0.133	0.246	0
20	1.929	0.128	1.759	0.132	0.247	0
21	1.756	0.128	1.998	0.132	0.257	0
22	1.733	0.127	1.933	0.132	0.254	0
23	2.001	0.126	1.925	0.132	0.254	0
24	1.926	0.125	1.532	0.131	0.234	0
25	1.785	0.124	2.155	0.129	0.261	0

Table C.6: WAVE STATISTICS: INCIDENT VS. REFRACTED

	INC SPECTRUM		REFRACTED SPECTRUM			
DEPTH(M)	0.42000		0.30000			
RANK	Tr	Hr	Tr	Hr	Hb	Ib
1	1.723	0.182	1.739	0.184	0.246	0
2	1.704	0.160	1.726	0.159	0.245	0
3	1.810	0.158	1.823	0.159	0.250	0
4	1.930	0.154	1.936	0.152	0.254	0
5	1.899	0.149	1.906	0.149	0.253	0
6	1.928	0.149	1.980	0.148	0.256	0
7	1.991	0.146	1.915	0.145	0.254	0
8	1.847	0.146	1.861	0.144	0.251	0
9	1.842	0.142	1.958	0.142	0.255	0
10	1.858	0.140	1.854	0.139	0.251	0
11	1.957	0.139	1.854	0.138	0.251	0
12	1.712	0.138	2.027	0.138	0.258	0
13	2.040	0.137	1.851	0.137	0.251	0
14	1.833	0.135	1.826	0.135	0.250	0
15	2.148	0.135	1.840	0.133	0.251	0
16	1.813	0.134	2.137	0.132	0.261	0
17	1.852	0.132	1.738	0.131	0.246	0
18	1.965	0.129	1.963	0.130	0.255	0
19	1.480	0.128	1.926	0.129	0.254	0
20	1.929	0.128	1.991	0.129	0.256	0
21	1.756	0.128	1.763	0.128	0.247	0
22	1.733	0.127	1.755	0.127	0.247	0
23	2.001	0.126	1.934	0.125	0.254	0
24	1.926	0.125	1.807	0.125	0.249	0
25	1.785	0.124	1.583	0.124	0.237	0

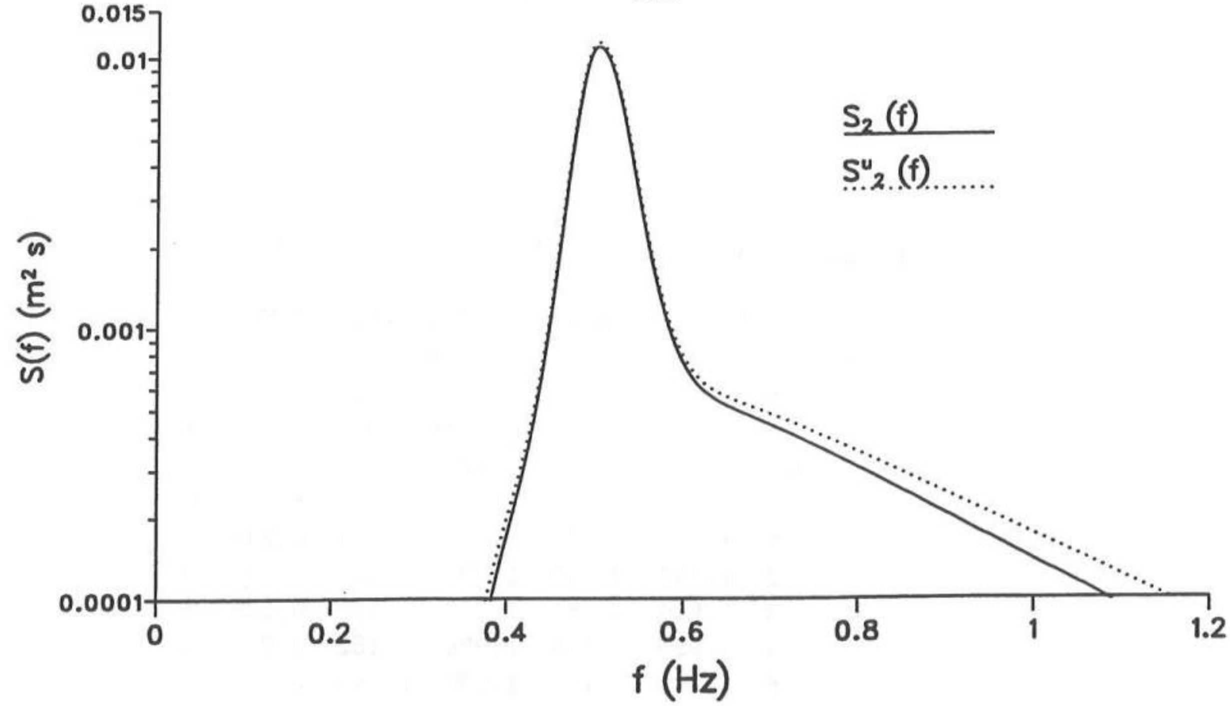

Figure C.1: Refracted Frequency Spectrum Versus Shoaled Uni-Directional Frequency Spectrum at Depth 2

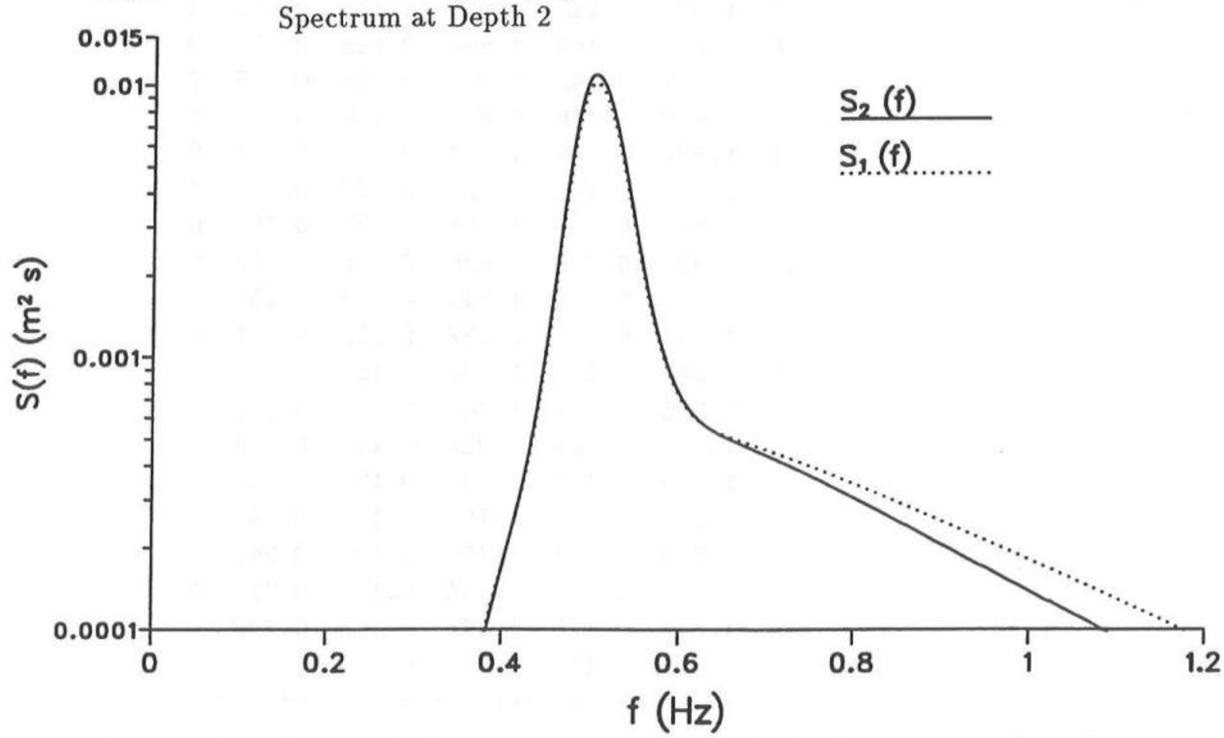

Figure C.2: Refracted Frequency Spectrum at Depth 2 Versus Incident Frequency Spectrum at Depth 1

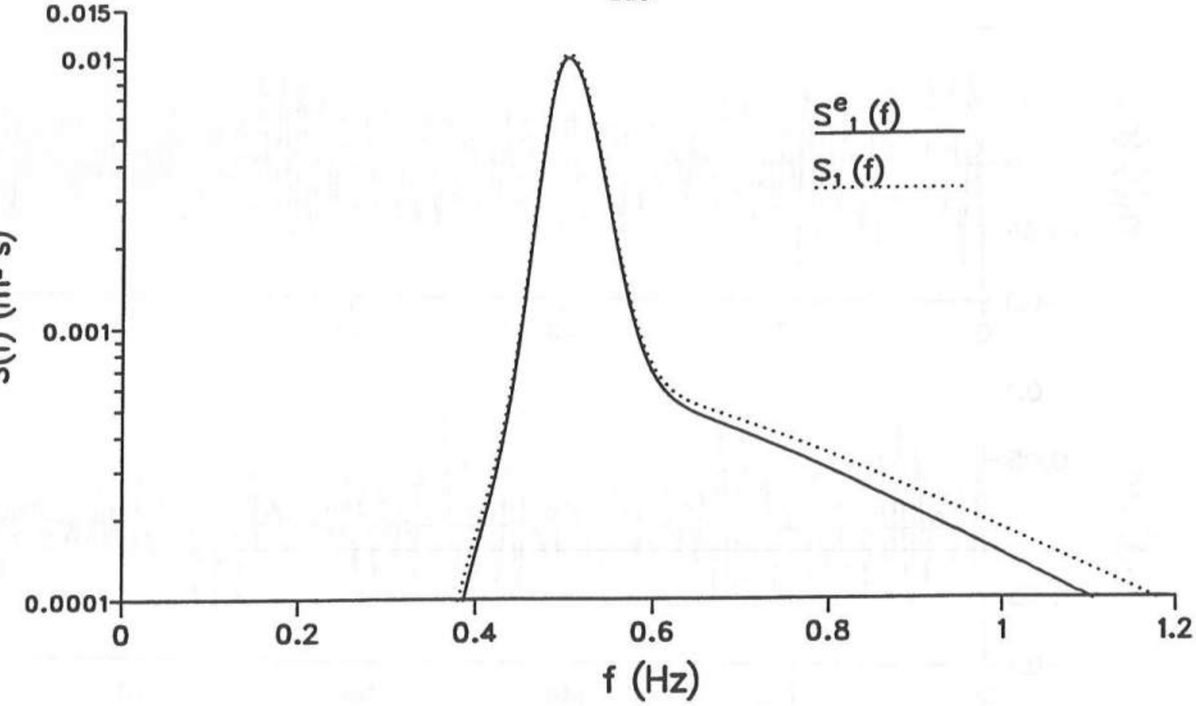

Figure C.3: Equivalent Uni-Directional Frequency Spectrum Versus Incident Frequency Spectrum at Depth 1

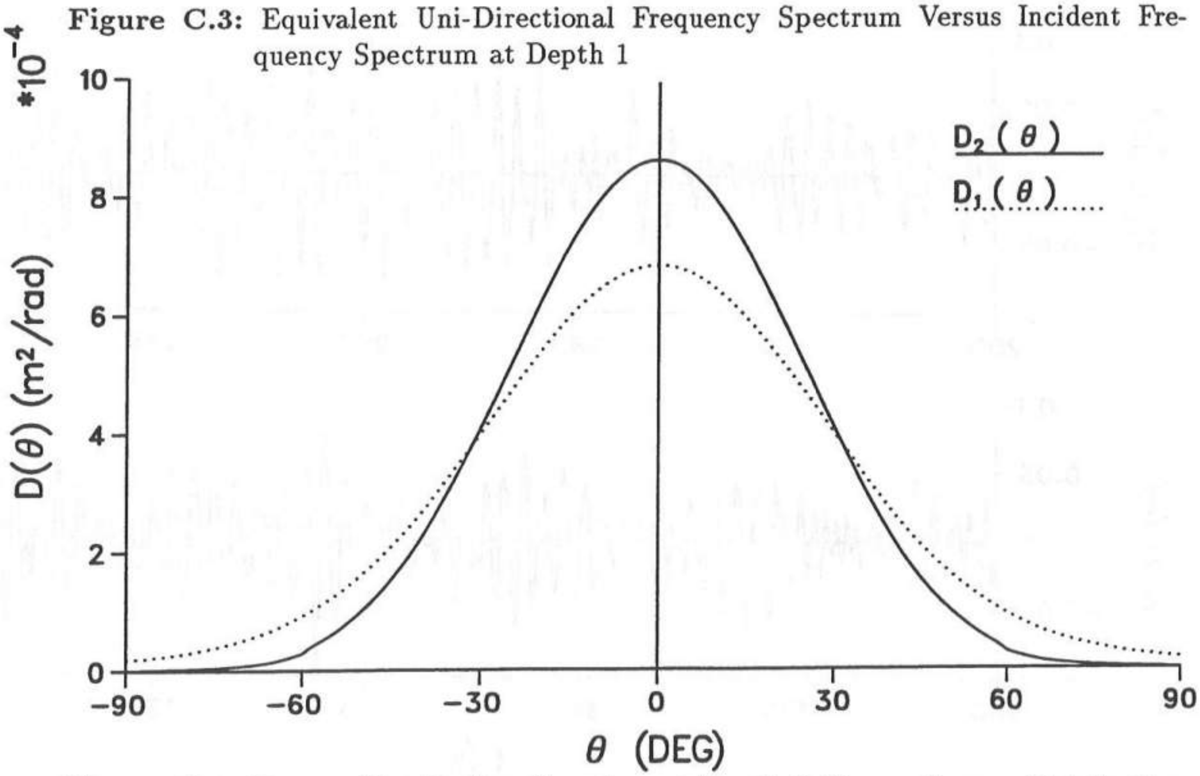

Figure C.4: Energy Distribution Function at Depth 2 Versus Energy Distribution Function at Depth 1

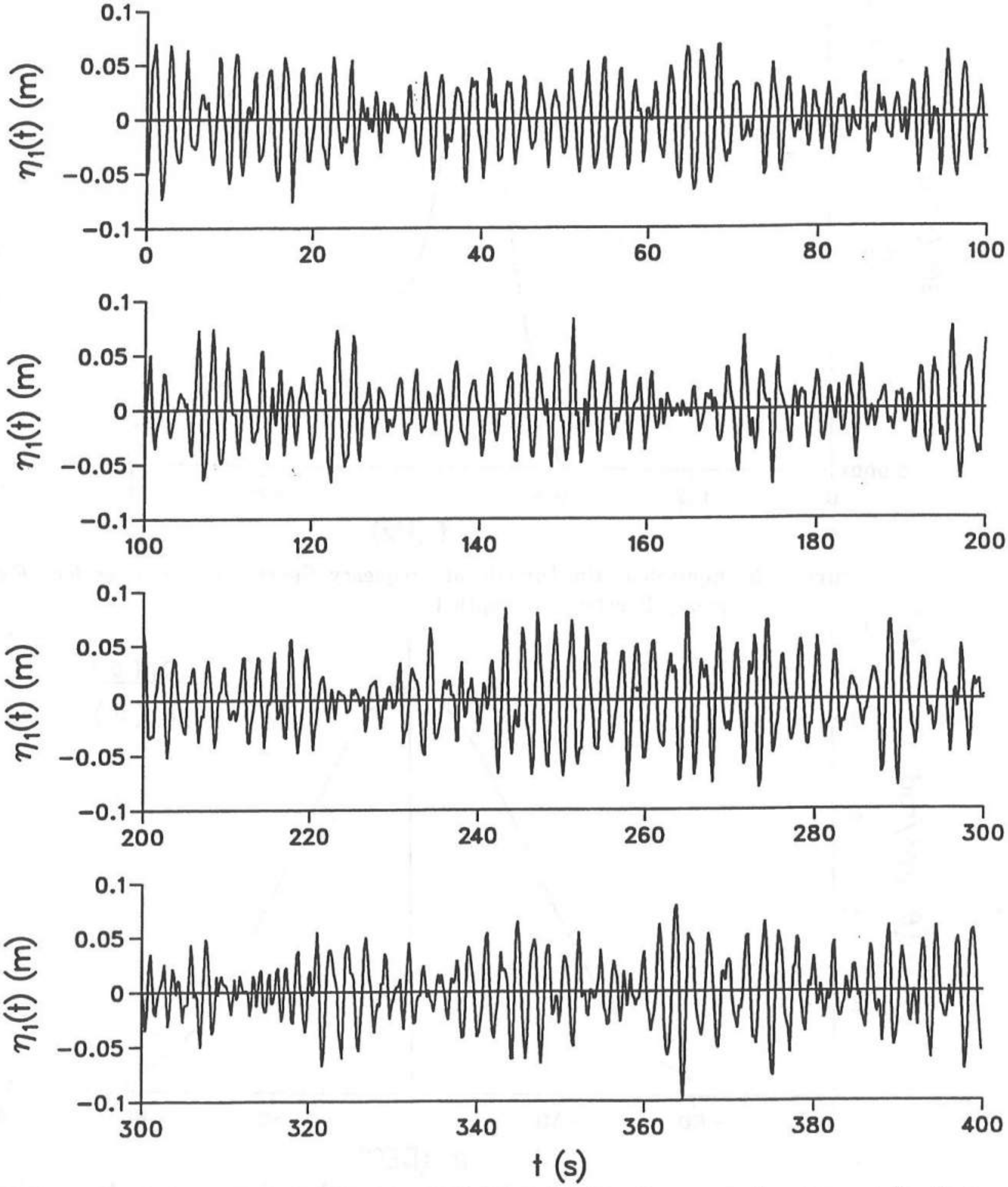

Figure C.5: Time Series Generated From Incident Frequency Spectrum at Depth 1, $\alpha_p = 0°$

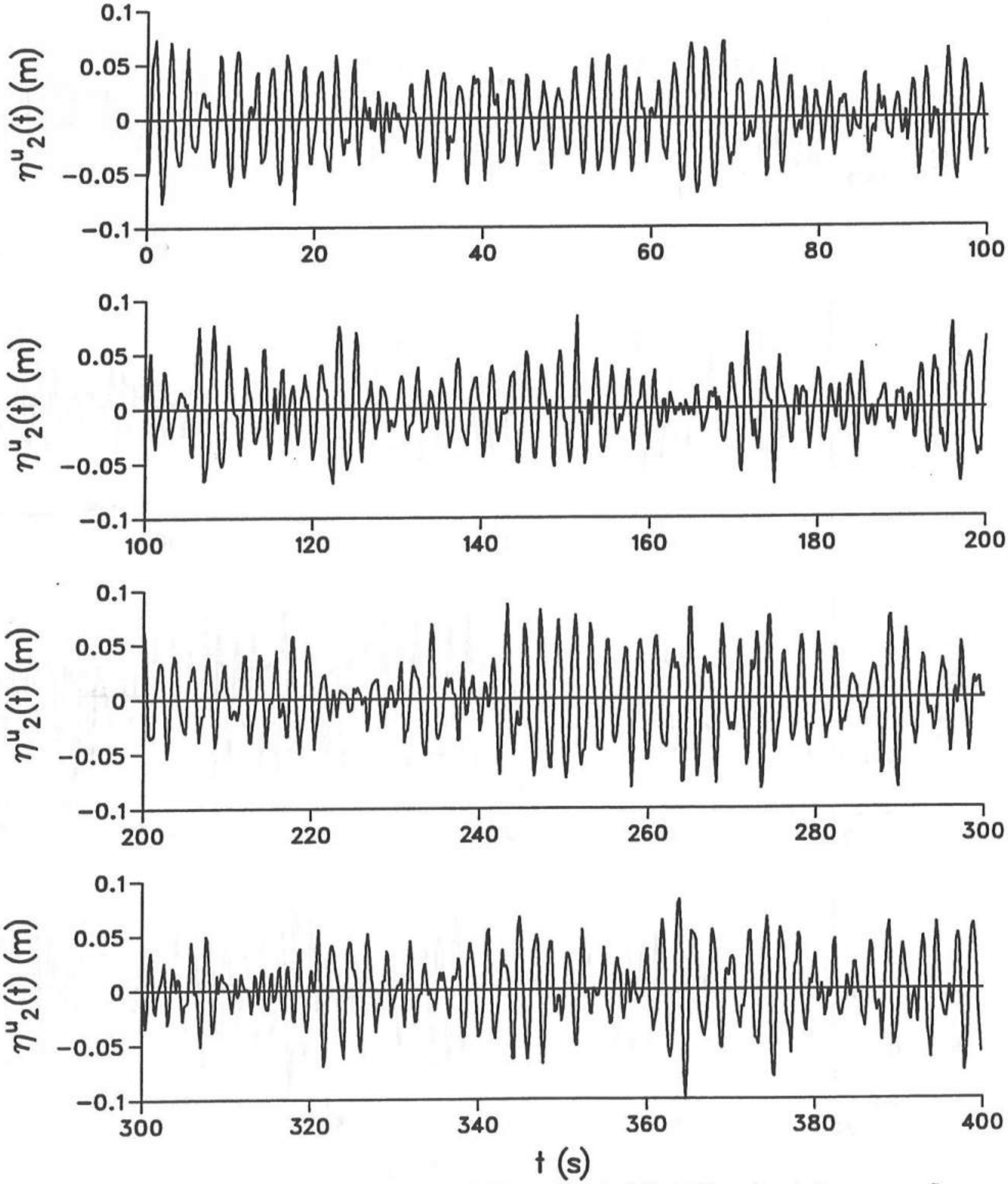

Figure C.6: Time Series Generated From Shoaled Uni-Directional Frequency Spectrum at Depth 2, $\alpha_p = 0°$

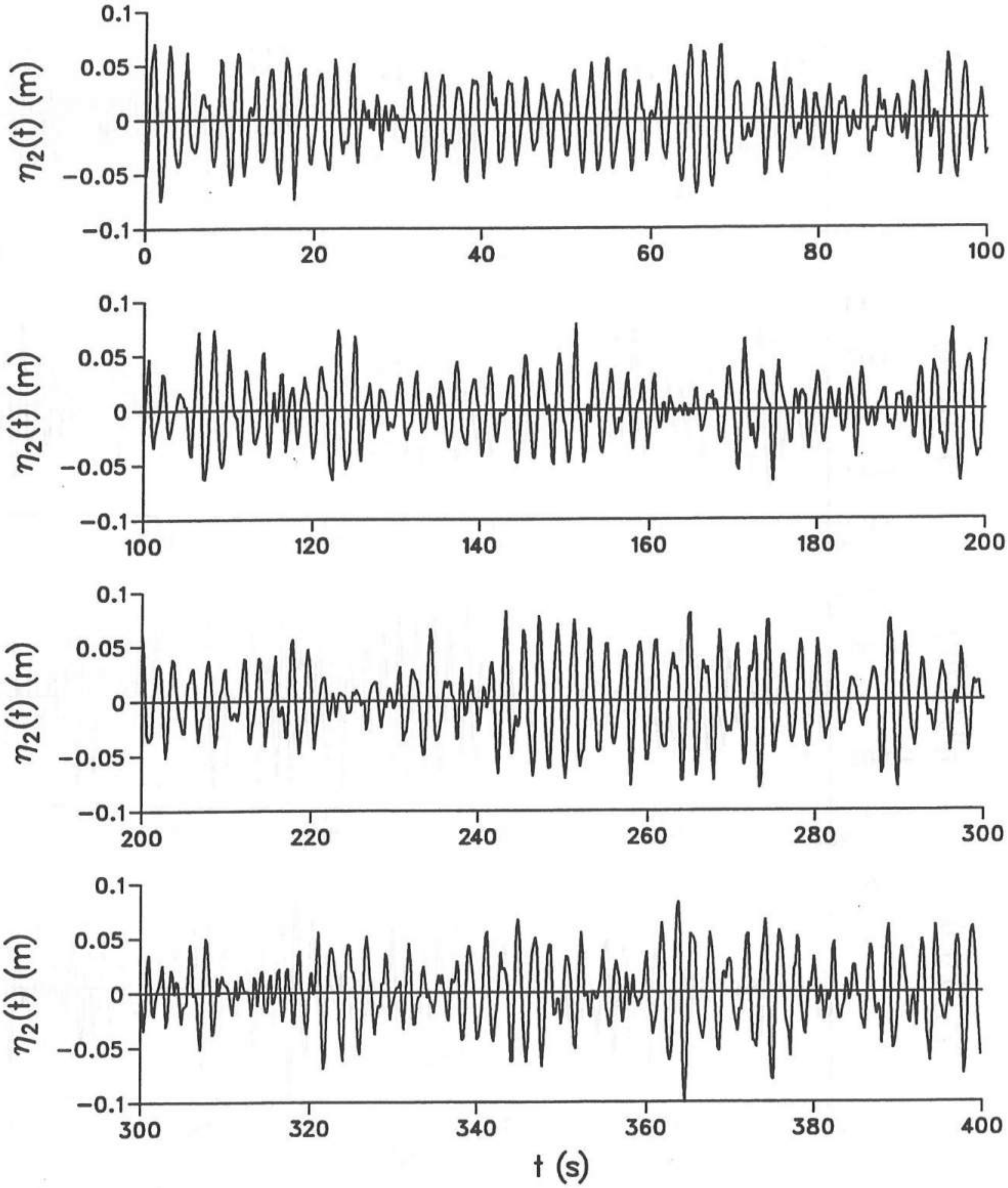

Figure C.7: Time Series Generated From Refracted Frequency Spectrum at Depth 2

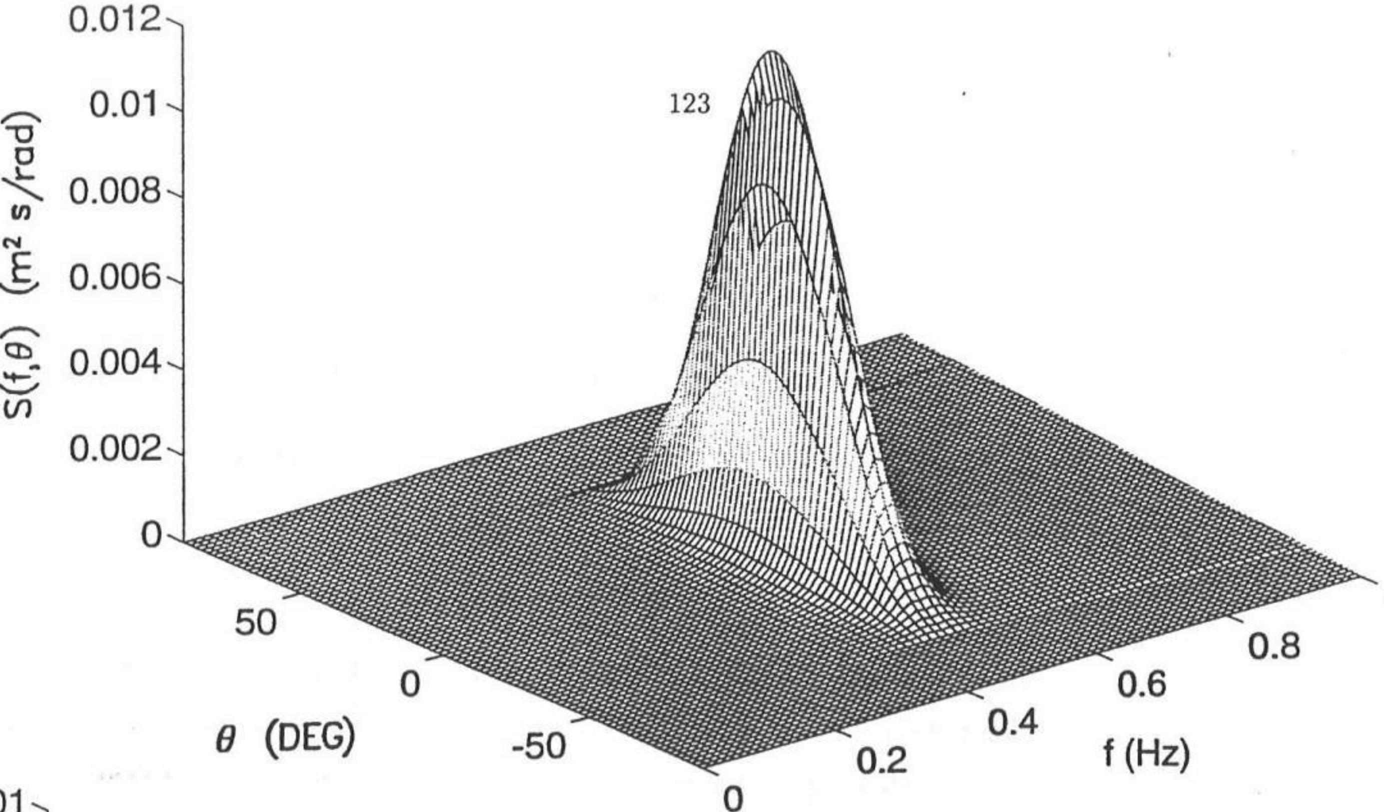

Figure C.8: Directional Spectrum at Depth 2 as a Function of Frequency and Direction

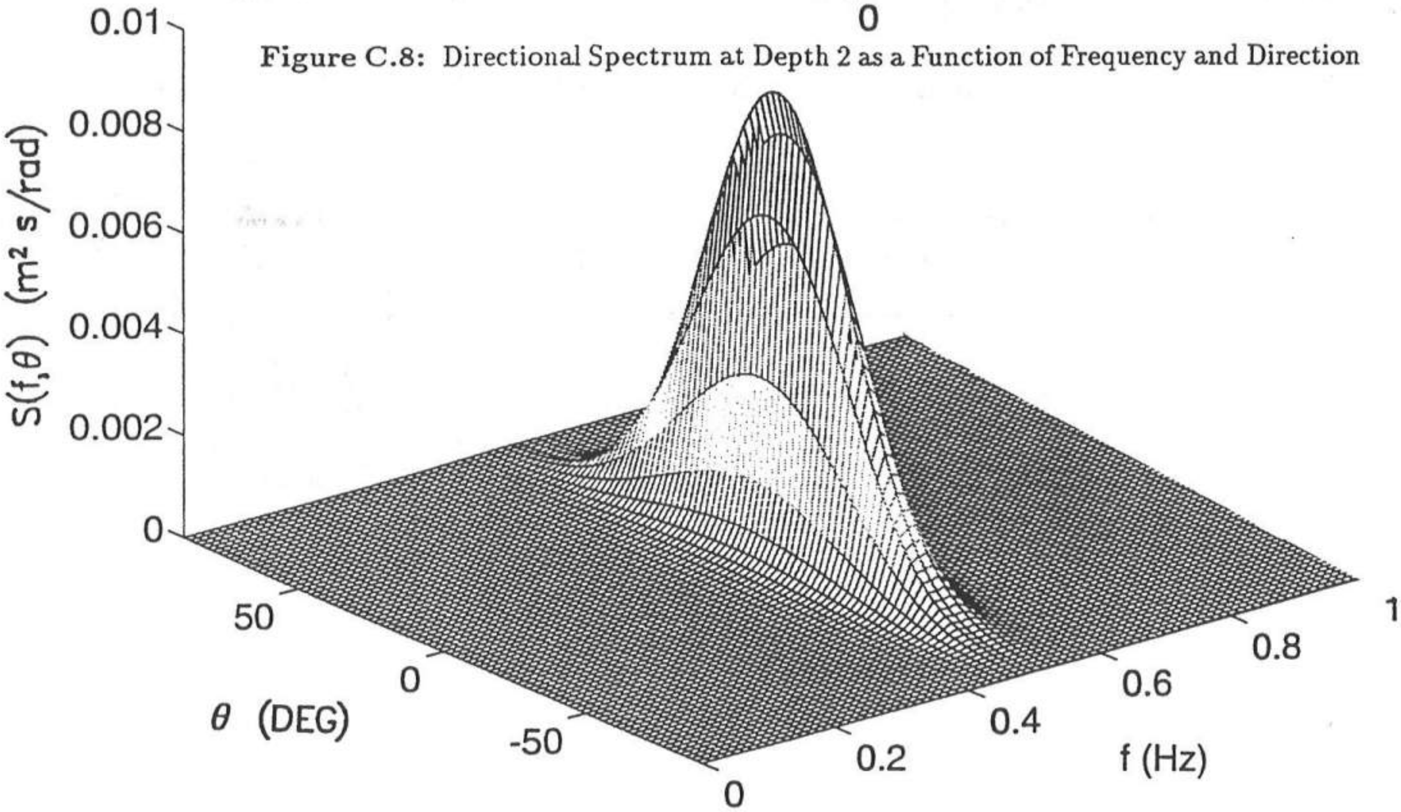

Figure C.9: Directional Spectrum at Depth 1 as a Function of Frequency and Direction

Appendix D

CONTENTS OF ACCOMPANYING DISK

This report is accompanied by a 3.5 inch, IBM-PC-formatted floppy disk containing computer files as listed in Table D.1. The general rule in naming the computer files is as follows: [*.for] = FORTRAN program and [*.inp] = the input data file. Also, the approximate computation time for each example is presented.

Table D.1: CONTENTS OF ACCOMPANYING DISK

DIRECTORY	NAME OF FILE ON DISK			REFERENCE
	PROGRAM	INPUT FILES	COMP TIME	
program	reshoal.for			Chapter III & Appendix A
appenb		appenb1.inp appenb2.inp	5 min 5 min	Appendix B Appendix B
appenc		appenc1.inp	5 min	Appendix C