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User's Guide for a Personal Computer Model of Turbulence at a Wind Turbine Rotor

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August 1989

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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SUMMARY

The Pacific Northwest Laboratory's (PNL) computational theoretical model of rotationally sampled wind turbulence (RODASIM11), having served its original purpose of verifying concepts and analyses of initial rotational measurements of wind speed, has been extended to include vertical-axis wind turbine configurations and two-dimensional turbulence velocity. It includes a mean wind shear at the user's discretion. The model produces not only spectral results but also time series of the wind experienced by individual points rotating as points on a wind turbine blade would rotate. For convenience, it may be simply modified to repeat the calculations for each radius in any prescribed set of radial positions without the need to resubmit the program code for each radial location chosen.

The turbulence velocities may be computed in either the rectangular coordinate system, or, for the vertical-axis wind turbine, the cylindrical coordinate system. For the horizontal axis of rotation, the through-disk component of wind speed is calculated. The locations of the wind calculated are given only in the cylindrical coordinate system. Thus, to be used with an aerodynamic or structural model that uses the rectangular position coordinates, the position coordinates of the turbulence model must undergo a simple standard position coordinate transformation applied by the user. No turbulence values are calculated for unused locations and times in the plane of rotation. The combination of the features described above makes possible a short computational time.

In its present form, the model includes a zero correlation (or, alternatively, complete correlation) between winds at any two locations on the rotor blades. Other distributions of the value of correlation might be specified; they are in some other models (e.g., by Veers 1988; Connell et al. 1988; and Thresher and Holley 1981, out to only twice the rotation frequency of the blade). However, we have chosen to await the availability of accurate determination of the value of those correlations for rotating blades in the atmospheric boundary layer before considering their inclusion in the model.

The source code and the executable code for the model were assembled to operate on a desktop computer. This document is primarily a user's guide for

the code and a brief guide to the growing literature on the subject of the rotationally sampled wind.

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1.0 INTRODUCTION

This document is primarily 1) a user's guide for the personal computer (PC) version of the code for the PNL computational model of the rotationally sampled wind speed (RODASIM11) and 2) a brief guide to the growing literature on the subject of rotationally sampled turbulence, from which the model is derived. The model generates values of turbulence experienced by single points fixed in the rotating frame of reference of an arbitrary wind turbine blade. The character of the turbulence depends on the specification of mean wind speed, the variance of turbulence, the crosswind and along-wind integral scales of turbulence, mean wind shear, and the hub height, radius, and angular speed of rotation of any point at which wind fluctuation is to be calculated.

Having served its original purpose of verifying concepts and analyses of initial rotational measurements of wind speed, RODASIM11 has been extended to include vertical-axis wind turbine configurations and two-dimensional turbulence velocity. The model produces, at the user's discretion, a measure of fluctuation caused by rotation through a mean wind shear. In addition to a computed spectral density function of the wind, time series of the wind, experienced by individual points rotating as points on a wind turbine blade would rotate, are produced. The calculations for each radius and angular position on the rotor in any prescribed set of positions are made in separate submittals of the present version of the program code. The seed selected for generating the time series determines whether there is correlation between different points or not. The present version of RODASIM11 models correlation only as complete or zero correlation.

The turbulence velocity components may be computed in either the rectangular coordinate system or, for vertical-axis wind turbines, the cylindrical coordinate system. For the horizontal axis of rotation, the through-disk component of wind speed is calculated. The locations of the wind calculated are given only in the cylindrical coordinate system. Thus, to be used with an aerodynamic or structural model that uses the rectangular position coordinates, the user must apply a simple standard position coordinate transformation to the position coordinates. No turbulence values are calculated for unused

locations and times in the plane of rotation. The combination of the features described above makes possible a short computational time.

Since the first publication on rotationally sampled wind characteristics (Connell 1980), an increasing number of variations, extensions, and different approaches to modeling of the rotationally sampled wind have appeared. Each model has contributed to the continuing improvement in understanding and application of the original concept. In addition to the references cited in this document, an extensive bibliography is appended to aid the reader in exploring the literature.

It is important to keep in mind that the present version of the model does not include the effects of the turbine rotor on the character of the inflowing turbulence and mean wind shear. That is, the model is a free-stream one. The distortion induced into the inflow by a rotor affects the character of the rotationally sampled turbulence and the mean wind shear and thus the aerodynamic forces on the blades (Neff, Meroney, and Connell 1987; Strickland 1987). The modification of the mean wind and the turbulence by flow distortion ahead of the rotor do not follow the same pattern. The present version of the model excludes flow distortion effects because they are not satisfactorily known, although the principles have been discussed in the literature (e.g., Moon, Piomelli, and Reynolds 1986; Wyngaard 1981; Britter, Hunt, and Mumford 1979).

An example of the output of the model, computed for a horizontal-axis wind turbine configuration, is given in Section 2. A corresponding example for a vertical-axis wind turbine configuration is given in Section 3. The user's guide to the computer code of the turbulence model is written as Section 4. A few concluding remarks about use and interpretation of the results are given in Section 5. The full computer code is listed in Appendix A; printed output for the examples is given in additional appendices.

2.0 EXAMPLE OF THE OUTPUT FROM THE MODEL FOR A HORIZONTAL AXIS OF ROTATION

The PC program creates a set of output files from which all input and output data and additional statistics of the output data are accessible. Examples of each of the files are described in this section. Samples of all of the data representative of cross-disk wind fluctuations observed at 0.5 and 1.0 times the radius of the MOD-OA horizontal-axis wind turbine (HAWT) blade for typical wind conditions in simple terrain are included either in this section or in the referenced appendices. The subsections are labeled by the name of the output file discussed therein. More comprehensive descriptions and definitions of the input and output variables for the code are given by Powell and Connell (1986). Selected portions of the cited report are included as Appendix B.

2.1 SUMMARY.DAT

The first page of SUMMARY.DAT (reproduced here as Table 2.1) describes the wind conditions and parameters and computational input parameters used to specialize the code for the MOD-OA wind turbine in typical wind conditions in simple terrain for a point at half the radius of the blade. Computed output values of autocorrelation, variance and spectra, etc., from the model are tabulated in the remaining pages of the file. Samples of all pages are included as Appendix C.

The power spectral density functions calculated from the model for the wind at the MOD-OA in simple terrain are shown in Figure 2.1. Figures 2.1a and b are for the half-blade radius and Figures 2.1c and d are for the full-blade or tip radius. The PC program does not include plotting routines, but only tabulates the data as shown in the tables.

2.2 SUMMARY.BRF

The summary sheet displays selected input parameters to the model and selected computed statistics for the winds computed by the model. An example for the same MOD-OA case is shown in Table 2.2.

TABLE 2.1. First Page of SUMMARY.DAT File

```

HAWT SIMULATION
SERIAL NUMBER HT050
RADIUS OF ROTATION 9.5 M
RATE OF ROTATION .6670 HZ
HUB HEIGHT 30.5 M
SURFACE ROUGHNESS LENGTH .0500 M
MEAN WIND SPEED 10.00 M/S
TURBULENCE RMS VALUES
  U-COMPONENT 1.497 M/S
  V-COMPONENT 1.497 M/S
TURBULENCE VARIANCES
  U-COMPONENT 2.241 (M/S)**2
  V-COMPONENT 2.241 (M/S)**2
FRICTION VELOCITY .624 M/S
TURBULENCE INTEGRAL LENGTH SCALES
  LONGITUDINAL 128.1 M
  LATERAL 51.2 M
NUMBER DATA TO BE SIMULATED 2048
DISCRETIZATION INTERVAL .0937 SEC
ALIAS FACTOR 4
ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
NANGLE WAS READ IN - DT WAS CALCULATED
ALFA, BETA .1864 .0188
LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
NUMBER OF HARMONICS IN SPECTRA 1024
THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
SPECTRUM AND REDUCED VERSION.
FUNDAMENTAL FREQUENCY IS .005211 HZ

MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
DIFFERENT FORMS OF VARIABLES:
  - ORIGINAL
  -A - INCLUDING EXTENSIONS ASSOCIATED WITH ALIAS REMOVAL
  -ND - DIMENSIONLESS VARIABLE
  -AND - BOTH OF THE ABOVE
DISCRETIZATION INTERVAL - DT
  .094 SEC
  -A .023 SEC
  -ND .196
  -AND .049
NUMBER OF SIMULATED DATA - MMT
  2048
  -A 8192
FUNDAMENTAL FREQUENCY - EN1
  .00521 HZ
  -ND .00249
NYQUIST FREQUENCY - EN2
  5.33800 HZ
  -A 21.34400 HZ
  -ND 2.54848
  -AND 10.18592
NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE
  16
  -A 64
HANNING WINDOW USED - LAST R BEFORE USE .0010
AUTOCORRELATION FUNCTION 3440 STEPS 80.58 SECONDS

```

a) HAWT SIMULATION (0.5 BLADE RADIUS)

b) HAWT SIMULATION (0.5 BLADE RADIUS), W/O MEAN

c) HAWT SIMULATION (1.0 BLADE RADIUS)

d) HAWT SIMULATION (1.0 BLADE RADIUS), W/O MEAN

FIGURE 2.1. The Power Spectral Density Function Calculated From the Model for the Wind at the MOD-OA in Simple Terrain. Curves a and b are for the half-blade radius and curves c and d are for the full-blade or tip radius.

TABLE 2.2. SUMMARY.BRF for the MOD-OA Case

```

HAWT SIMULATION
SERIAL NUMBER HT100
RADIUS OF ROTATION 19.0 M
RATE OF ROTATION .0670 HZ
HUB HEIGHT 30.5 M
SURFACE ROUGHNESS LENGTH .0500 M
MEAN WIND SPEED 10.00 M/S
TURBULENCE RMS VALUES
  U-COMPONENT 1.497 M/S
  V-COMPONENT 1.497 M/S
TURBULENCE VARIANCES
  U-COMPONENT 2.241 (M/S)**2
  V-COMPONENT 2.241 (M/S)**2
FRICTION VELOCITY .624 M/S
TURBULENCE INTEGRAL LENGTH SCALES
  LONGITUDINAL 128.1 M
  LATERAL 51.2 M
NUMBER DATA TO BE SIMULATED 2048
DISCRETIZATION INTERVAL .0937 SEC
ALIAS FACTOR 4
ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
ANGLE WAS READ IN - DT WAS CALCULATED
ALFA, BETA .3708 .0186
LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
NUMBER OF HARMONICS IN SPECTRA 1024
THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
SPECTRUM AND REDUCED VERSION.
FUNDAMENTAL FREQUENCY IS .005211 HZ

MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.1012 (M/S)**2
VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM
S(N)C, - (M/S)**2
.7683 .7603 .2383 .1200 .0754 .0530 .0400
RMS
.8765 .8720 .4881 .3464 .2746 .2303 .1999
SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
.5600 .0832 .0237 .0119 .0074 .0051 .0037
VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
SPECTRUM OF SIMULATED DATA, S(N)R
.7303 .5693 .2244 .1190 .0753 .0530 .0400
VARIANCE OF S(N)R FROM SIMULATED DATA 1.8559
SKEWNESS AND KURTOSIS -.0028 2.8664
ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT
VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
SPECTRUM OF SIMULATED DATA, S(N)R
.7303 1.5054 .2144 .1169 .0760 .0531 .0400
VARIANCE OF S(N)R FROM SIMULATED DATA 2.7808
SKEWNESS AND KURTOSIS -.0535 2.7323

```


2.3 SERIES.DAT

The SERIES.DAT file contains the complete time series of wind speed values computed. A sample of the complete file for the case at half radius, including mean wind shear, and producing a total of 2048 data in the time series, is included as Appendix D. Section D.1 contains a sample of the file for the turbulent part of the wind only. Section D.2 includes the first part of the listing of the fluctuations caused by rotation through the total wind, which is made up of the turbulence and the mean wind. Samples of the time series of through-disk wind speed generated for the MOD-0A conditions in simple terrain are shown in Figure 2.2. Figures 2.2a and b show the fluctuation of wind speed including the effect of the mean wind shear. Figures 2.2c and d show the fluctuation observed with the mean wind shear removed.

2.4 THE OUTPUT FILES FOR THE FULL RADIUS CONDITION OF THE MOD-0A

The first portion of each of the files for a radius equal to the tip radius (19 m) of the MOD-0A, but otherwise corresponding to the output file conditions discussed in the previous sections, is included in Appendix E.

FIGURE 2.2. Samples of the Time Series of Cross-disk Wind Speed Generated for the MOD-0A Conditions in Simple Terrain for a Time Increment of 15 s, or 10 Revolutions of a Rotor Blade. Curves a and b show the fluctuation of wind speed including the effect of the mean wind shear. Curves c and d show the fluctuation observed with the mean wind shear removed.

3.0 EXAMPLE FOR A VERTICAL AXIS OF ROTATION

The output files for the vertical-axis wind turbine (VAWT) case are formatted like the files for the horizontal axis of rotation. The two sets of examples are for the radial (normal to a circumference) and tangential wind components at the equatorial radius rather than for the single component in the HAWT case at two radii presented in Section 2. Samples of all the files are included in Appendix F. They are for a 34-m Darrieus rotating at 0.5 rev/s in typical wind conditions in simple terrain. The spectral density functions for the radial and tangential components of the wind fluctuation are plotted in Figure 3.1. The radial fluctuations including mean wind are in Figure 3.1a, and without the mean wind in Figure 3.1b. The tangential fluctuations including the mean wind are in Figure 3.1c, and without the mean wind in Figure 3.1d. Samples of the corresponding time series for 20 s, or 10 rotations of the specified 34-m Darrieus, are shown in Figure 3.2.

FIGURE 3.1. The Spectral Density Functions for the Radial and Tangential Components of the Wind Fluctuation at the Equatorial Point of the Blade of the 34-m Darrieus. The radial fluctuations including mean wind are shown by curve a, and without the mean wind by curve b. The tangential fluctuations including the mean wind are shown by curve c, and without the mean wind by curve d.

FIGURE 3.2. Samples of the Time Series for 20 s or 10 Rotations Corresponding to Figures 3.1a, b, c, and d

4.0 THE COMPUTER PROGRAM

The executable file that is supplied with the user's guide should run on any IBM-PC^(a) or compatible personal computer. In the event that it does not, or should the user wish to optimize the code for the machine that it will be running on, the FORTRAN77 source code is printed in Appendix A.

4.1 THE EXECUTABLE FILE: THEORY.EXE

The executable program was compiled on an IBM-PC^(a) with 640K of memory using Microsoft's FORTRAN compiler version 4.01^(b). Command line flags were set to allow for variables with names longer than six characters and to optimize the code. Because of the size of the code, we advise having a two-drive system or one with a hard drive to run the program, although it can be run on a one-drive system.

The maximum size of turbulence time series that can be run without recompiling the program, 2048 data points, is the 360K storage limit of the floppy disk on which PNL records the code. This may be too few data points for some purposes, such as wanting to have velocity at 100 points around the ring of rotation or wanting data for more than the 20.48 blade rotations that this condition implies.

In order to increase the number of data points simulated, it is necessary to edit the RODASIM.INC file (see Table 4.1) to increase the magnitude of the exponent, NEXP (see Table 4.2), specifying the size of the time series in powers of two to an integral value greater than 11, e.g., 4096, or 8192 points. The other parameters in RODASIM.INC are automatically calculated as extensions of NEXP. After NEXP is changed, the program will have to be recompiled and available storage will have to be larger in order to run the program. Compiling time using an IBM-PC is about 15 min.

(a) IBM-PC is a product of the International Business Machines Corporation, Boca Raton, Florida.

(b) Microsoft Corporation, Bellevue, Washington.

TABLE 4.1. Files on Disk Including RODASIM.INC

A_THRY	EXE	236234	9-24-88	8:24a
A_THRY	FOR	34831	9-24-88	8:08a
BESSEL	FOR	2716	9-23-88	11:13a
COOLEY	FOR	1606	9-23-88	11:13a
FFT	FOR	1052	9-23-88	11:14a
HAWTMN	FOR	395	8-08-88	12:41p
LOGBAND	FOR	3642	9-23-88	11:15a
RANDOM	FOR	1616	9-23-88	11:16a
RODAPRIN	FOR	4222	9-23-88	11:17a
VAWTTN	FOR	3186	9-23-88	11:18a
VAWTTNMN	FOR	638	9-23-88	11:18a
VAWTUV	FOR	2123	9-23-88	11:19a
RODASIM	INC	266	11-21-87	10:35p

TABLE 4.2. RODASIM.INC, The Include File
Needed for Compiling

```

PARAMETER (NEXP = 11)
PARAMETER (MMT = 2**NEXP)
PARAMETER (M2MT = 2 * MMT)
PARAMETER (MMT2 = MMT/2)
PARAMETER (ILIAS = 4)
PARAMETER (MMTA = ILIAS * MMT)
PARAMETER (MMTA2 = MMTA/2)
PARAMETER (JTCPL = 1 + MMT2)

```

4.1.1 Executing the Code

To execute the code on a single disk-drive system:

- 1> Place the PNL Theory disk in drive A.
- 2> Type A_THRY<RET> to execute the program.
- 3> When the program is finished loading, remove the program disk and replace it with a blank disk; the resulting data files will use approximately 200K of disk space during the program run.
- 4> Answer the prompts that the program supplies.
- 5> When the program finishes its run, rename the files created so that the program will run correctly when it is next used.

To execute the code on a dual disk-drive system:

- 1> Place the PNL Theory disk in drive B and a blank disk in drive A.
- 2> Type from the A> prompt B:A_THRY to execute the program.
- 3> Answer the prompts that the program supplies.
- 4> When the program finishes its run, rename the files created so that the program will run correctly when it is next used.

To execute the code on a hard-drive system:

- 1> Copy the file A_THRY.EXE from the PNL Theory disk to a hard-drive volume.
- 2> Set the directory to that volume and type the command A_THRY to execute the program.
- 3> Answer the prompts that the program supplies.
- 4> When the program finishes its run, rename the files created so that the program will run correctly when it is next used.

4.2 INPUT AND OUTPUT FROM THE PROGRAM

The program prints to the screen several prompts for input and generates three text files upon completion. The text files contain the information provided by the user as well as a simulated time series of data and the statistical information needed to create the time series.

4.2.1 A Sample of the Prompts That the Program Generates

The following is a sample of the prompts that the program generates for the horizontal axis wind turbine. NOTE: In this section values entered by the user in response to prompts appear underlined and explanatory comments that are not part of the prompts are enclosed in square brackets.

PNL Mathematical Theory for Rotationally Sampled Wind

Option:

- 1 - Do HAWT SIMULATION [horizontal wind speed fluctuations are simulated]
- 2 - Do VAWT U SIMULATION [component in the direction of the mean wind]
- 3 - Do VAWT V SIMULATION [crosswind horizontal component]
- 4 - Do VAWT TANGENTIAL SIMULATION
[component in the direction of the rotation of
the blade]
- 5 - Do VAWT NORMAL SIMULATION
[horizontal radial component]

Enter analysis option

1

Add mean wind to the simulated turbulence? (0=no,1=yes)

[The mean wind is calculated using the logarithmic
law from a specification of the roughness length
and a wind speed]

1

Enter offset angle between mean wind effect and 1P harmonic of simulated
turbulence (degrees)

[The mean wind speed will result in a fluctuation
component almost entirely at the rotation frequency
of the blade. The phase between the 1-P component
from the mean wind and that from the turbulence
may be taken to be 0° in lieu of other
information.]

0.

Enter simulated blade RADIUS (m)

20.

Enter blade rotation rate (cycles/s)

2.

Enter hub height (m)

30.

Enter Hub height wind speed (m/s)

10.

Enter surface roughness length (m) [z_0]

.05

Calculate the sigma-u,v from neutral boundary layer theory?

(0=yes, 1=read from keyboard)

0

Calculate turbulence length (m) at hub height using programmed formula?

(0=yes, 1=read from keyboard)

0

Assign value of rotational step, DT or NANGLE

(0=NANGLE is known, 1=DT is known)

[DT is the time step, NANGLE is the number of
equally spaced rotational points of simulation
around the circle of rotation.]

0

Enter number of divisions around the circle for simulation

16

Calculate autocorrelation and spectrum functions using smoother (Hanning)

(0=No, 1=Enter window function factor)

[The spectrum is calculated from an autocorrelation
function specified in the rotating frame of
reference (see Connell 1982). The smoother
option uses the Hanning technique for reducing
error in spectral shape that results when a finite
length autocorrelation has not converged
sufficiently close to zero (see Bendat and Piersol
1971, Sect 9.5.)

1

Enter the magnitude, in $(\text{m/s})^2$, that is to be compared with the calculated
raw autocorrelation function in deciding that the calculated function is close
enough to zero.

[This truncation saves computational time while
preserving the accuracy of the spectral repre-
sentation to follow.]

.001

[Recommended.]

Enter the seed for the pseudo-random number generator

[Keep seed value fixed in runs for other radii if
wind speeds at different radii are to be highly
correlated with each other.]

32767.D0

Enter the label for the run

'TEST1'

Spectrum computation finished...

Writing Simulated data...

Writing Simulated data...

--- End of program ---

4.2.2 A Description of the Output Files Generated

The sample texts of these files are printed in Appendices because of their size and format.

SERIES.DAT	-	Text file containing the time-series data simulated by the model (Appendix D).
SUMMARY.DAT	-	Text file containing all of the pertinent statistical data from which the time-series is calculated, including the input data (Appendix C).
SUMMARY.BRF	-	A brief summary of the SUMMARY.DAT file (Table 2.2).

5.0 CONCLUDING REMARKS

In its present form, the model includes either complete correlation between winds at any two locations on the rotor blades, or, alternatively, zero correlation, depending on selection of a seed for the random time generator used. Other specifications of the value of correlation might be made, as they are in some other models (e.g., Veers 1984, 1988; Connell et al. 1988; Thresher and Holley 1981). However, we have chosen to await the availability of accurate determination of the value of those correlations for rotating blades in the atmospheric boundary layer before considering their inclusion in a model. A specified correlation might be artificially constructed by the user, but further evaluation of its validity is required.

The model has the unique feature of incorporating separate length scales for the along-wind and crosswind directions. This feature, an empirical extension of the model basis of homogeneous, isotropic turbulence, allows simulation for a wider range of turbulence conditions. The user may determine how to use these two length scales to simulate conditions of interest, and both can be taken to have the same value.

The source code and the executable code for RODASIM11, along with a sample of the output from an execution of the program, were written on floppy disks so that they could be run on desktop rather than mainframe computers. This document is primarily a user's guide for the PC version of the code, and, through its references and bibliography, a guide to the growing literature on the subject of the rotationally sampled wind.

6.0 REFERENCES

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NOTE: Appendix G presents a bibliography of other publications on turbulence and rotational sampling.

APPENDIX A

THE PNL THEORETICAL TURBULENCE MODEL SOURCE CODE

APPENDIX A

THE PNL THEORETICAL TURBULENCE MODEL SOURCE CODE

\$LARGE

PROGRAM RODASIM11

CCCC

* The principal function of the main program is to provide
* parameterization that can be used to generate an autocorrelation
* function that corresponds to wind variation experienced by a point
* on a rotating wind turbine blade, either HAWT or VAWT. For HAWT the wind
* direction is perpendicular to the plane of blade rotation. The parameter-
* ization is from a memo by J. R. Connell. For the VAWT there are four
* optional definitions for the turbulent wind:

* u - parallel to mean wind
* v - perpendicular to mean wind
* t - tangential to rotating surface
* n - normal to rotating surface

* (In the user's guide the n component is called the r component,
* meaning radial).

* In each case the autocorrelation function is computed in a SUBROUTINE
* BESSEL and returned to this program so that the corresponding logarithmic
* power spectrum can be computed.

* The main program computes two versions of the spectral density $S(n)$.
* One is by Fourier transformation of the autocorrelation function, and
* is really a vestige of a previous program. The $S(n)$ used is produced
* by harmonic analysis over the frequency domain from the reciprocal
* of the time period of the sample to the Nyquist frequency. This
* spectrum is saved for later plotting to compare with a similar spectrum
* generated as follows.

* The square root of all members of $S(n)$ is taken and an impulse
* response function $h(t)$ is produced. This is convolved with Gaussian
* white noise to produce simulated data. The spectrum $S(n)$ of these
* data is computed by harmonic analysis by still another program. This
* version is compared to the $S(n)$ spectrum produced in the present program,
* and the degree of correspondance is part of the measure of success of the
* simulation.

CCCC

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* DEFINITIONS:

* Some of the variables exist in one to three versions in addition to
* the original, as is shown by the final letters, A, ND, or AND.

* The A final means that this value was needed to compute the complete
* aliased spectrum. For example if DT, the discretization interval is
* 2., DTA will be (2.*ILIAS).

* The ND final means that this version of the variable is dimensionless.
* The AND final means that both effects are combined.

*
 * DELAY - offset angle between mean wind effect and 1P harmonic
 * of simulated turbulence (degrees)
 * ALFA is the ratio of blade radius to turbulence length scale.
 * ANGLE - Phase angle of 1P harmonic in simulated data. Zero value
 * indicates a cosine wave (degrees).
 * ANGLEA - The angle the tangent or normal to the circle at the initial
 * position makes with the mean wind direction (degrees).
 * It is now defined in Subroutine VAWTTN.
 * BETA is the ratio of ALFA to tip speed ratio $\Omega \cdot RADIUS / U$.
 * CHK is the highest final value that will be accepted in an auto-
 * correlation function without windowing (Hanning).
 * CMMT - number data to be simulated.
 * CMMTA
 * DT - the data discretization interval in seconds.
 * DTA, DTND, DTAND
 * D1() - final simulated data.
 * D1M() - one cycle of mean wind simulation.
 * EL1 is the turbulence length scale in beta, $(Lu)_x$.
 * EL2 is the turbulence length scale in alfa, $(Lu)_y$.
 * ENL() - frequencies n in Hz. These are linearly spaced and limited in
 * number to 80.
 * ENLND()
 * ENL1() - Frequencies for 20 divisions of the first band of ENL().
 * ENL1ND()
 * ENP() - Cyclic frequency in terms of blade rotation rate (so many P).
 * ENO is the blade rotation rate in cycles per second.
 * EN1 - lowest frequency for which spectral computation is possible -
 * reciprocal of data length - fundamental frequency - Hz
 * EN1ND
 * EN2 - Nyquist frequency - highest frequency for which spectral
 * computation is possible - Hz.
 * EN2A, EN2ND, EN2AND
 * G1() - white noise
 * HT1
 * IFFSET - Number of positions mean wind wave is to be shifted
 * before adding to simulated turbulence.
 * ILIAS is the reciprocal of the fraction of the spectrum that is
 * regarded as fit to retain because aliasing can be ignored.
 * For example: ILIAS = 1 - Retain all of the spectrum.
 * = 2 - Retain the lower frequency half.
 * = 4 - Retain the lower frequency quarter.
 * Recommended values are 2 or 4.
 * KAWT - option: 1 - Do HAWT u analysis and simulation
 * 2 - Do VAWT u "
 * 3 - Do VAWT v "
 * 4 - Do VAWT t "
 * 5 - Do VAWT n "
 * KMAX is the maximum number of arguments that may be computed
 * for the autocorrelation function.
 * KSG is an option
 * 0: Calculate SIGU from neutral boundary layer theory.

```

*      1: Use SIGU as read in.
*      KWINDOW - additional option to turn off windowing.
*                = 0, windowing is bypassed regardless of character of acf.
*      K9....K16 are options to write to LU 9.....16
*      K9 - Write S(n) spectrum to disc
*            a) FFT of original acf
*            b) S(n) of simulated data
*      K11 - Write S(n) from cosine integration of acf to file (needed?)
*      K12 - Write simulated data to file.
*      K13 - Write n and von Karman S(n) to file.
*      K14 - Write complex Fourier coefficients of simulated data to file
*      K15 - Write banded nS(n) spectra of simulated data, preceded by
*            unbande nS(n) for lowest frequencies.
*      MMT is the number of data to be simulated.
*      MMTA
*      NHAR is the number of unbande spectral estimates S(n) to be
*            written to output file.
*      OMEGA is blade rotational rate (radians/sec).
*      R() - a timelag autocorrelation function generated in SUBROUTINE
*            BESSEL.
*      RADIUS is blade radius (m).
*      SIGU is the rms value for u (u-component turbulence), (m/s).
*      SIGU2 is the corresponding variance (m/s)**2.
*      SIGV, SIGV2 - same for v-component turbulence (m/s).
*      SPECL() - S(n) for linearly spaced frequencies - (m**2/sec)
*      SPECLND()
*      SPECL1() - S(n) for 20 divisions of the first band of SPEC().
*      SPECL1ND()
*      T - running dimensionless time - summation of increments of DTAND.
*      TMAX is dimensional max time for autocorrelation function.
*      U is wind speed (m/s) at height Z.
*      USTAR2 is the square of the corresponding friction velocity (m/s)**2.
*      VKSPEC() - S(n) according to Von Karman - same frequencies as SPECL().
*      XIF1(N) is the power spectral density S(n) (m**2/s**3)
*      Z is hub height (m).
*      Z0 is surface roughness length (m).
C*****

```

```

$INCLUDE: 'RODASIM.INC'

```

```

real*8 DSEED
CHARACTER KSERIAL*5
CHARACTER KAWTER(5)*30
COMPLEX XTEND, AN1, HALF
DIMENSION D1(MMT), XIF1(JTCPL), XVK(JTCPL), XVKA(JTCPL)
DIMENSION R(MMTA2), XTEND(MMTA), G1(JTCPL)
DIMENSION ENL(80), ENP(80), SPECL(80), ENL1(20), SPECL1(20)
DIMENSION ENLND(80), SPECLND(80), ENL1ND(20), SPECL1ND(20)
DIMENSION HT1(2000), SMOM(4)
DIMENSION DCOS(90), DSIN(90), D1M(90), PVAR2(7), VKSPEC(80)

```

```

COMMON DT, DTA, DTND, DTAND, EN1, EN1ND, EN2,
*EN2A, EN2ND, EN2AND, NANGLE, NANGLEA, RADIUS, ENO, Z, U,

```

```

*Z0, KSG, SIGU, SIGV, EL1, EL2, KNDOPT,
*KWINDOW, CHK, KMAX, NHAR, USTAR, ALFA, BETA, SIGU2,
*SIGV2, PVAR(7), PRMS(7), PVARVK(7)

```

```

EQUIVALENCE (R, D1)
*   VKU is the Von Karman u-spectrum. VKUD is the denominator of VKU.
VKUD(ENVK) = (1.0 + 70.78 * ENVK**2)**0.833333
VKU(ENVK) = 4.0 * ENVK / VKUD(ENVK)
*   VKUA is the altered Von Karman u-spectrum.
VKUDA(ENVK) = (1.0 + 39.48 * ENVK**2)**0.833333
VKUA(ENVK) = 4.0 * ENVK / (1.339 * VKUDA(ENVK))
*   Following are the corresponding v-spectra.
VKVN(ENVK) = 1.0 + 188.75 * ENVK**2
VKVD(ENVK) = (1.0 + 70.78 * ENVK**2)**1.833333
VKV(ENVK) = 2.0 * ENVK * VKVN(ENVK) / VKVD(ENVK)
*   altered v
VKVNA(ENVK) = 1.0 + 105.28 * ENVK**2
VKVDA(ENVK) = (1.0 + 39.48 * ENVK**2)**1.833333
VKVA(E) = 2.0 * E * VKVNA(E) / (1.339 * VKVDA(E))

DATA KAWTER/'HAWT SIMULATION','VAWT U SIMULATION',
*'VAWT V SIMULATION','VAWT TANGENTIAL SIMULATION',
*'VAWT NORMAL SIMULATION'/
PI = 3.141592654
TWOPI = 2.0 * PI
HALF = (0.5, 0.0)
MWINDFLAG = 0

```

```

c
c *** Read in the input parameters that the user has control of
c
  write(*,*) char(12)
  write(*,*) 'PNL Mathematical Theory for Rotationally Sampled Wind'
  write(*,*)
1  continue
  write(*,*) 'Option:'
  write(*,*) '  1 - Do ',kawter(1)
  write(*,*) '  2 - Do ',kawter(2)
  write(*,*) '  3 - Do ',kawter(3)
  write(*,*) '  4 - Do ',kawter(4)
  write(*,*) '  5 - Do ',kawter(5)
  write(*,*) 'Enter analysis option'
  READ(*,*,err=1) kawt

2  continue
  write(*,*) 'Add mean wind to the simulated'
  write(*,*) ' turbulence? (0=no,1=yes)'
  READ(*,*,err=2) mwind
  if (mwind.eq.0.) then
    delay = 0.
    go to 4
  end if

```

```

3      continue
      write(*,*) 'Enter offset angle between mean wind effect and 1P'
      write(*,*) ' harmonic of simulated turbulence (degrees)'
      READ(*,*,err=3) delay
      write(*,*)

4      continue
      write(*,*) 'Enter simulated blade RADIUS (m)'
      READ(*,*,err=4) radius

5      continue
      write(*,*) 'Enter blade rotation rate (cycles/sec)'
      READ(*,*,err=5) en0

6      continue
      write(*,*) 'Enter hub height (m)'
      READ(*,*,err=6) z

7      continue
      write(*,*) 'Enter Hub height wind speed (m/sec)'
      READ(*,*,err=7) u

8      continue
      write(*,*) 'Enter surface roughness length'
      READ(*,*,err=8) z0

9      continue
      write(*,*) 'Calculate the sigma-u,v from neutral boundary'
      write(*,*) ' layer theory? (0=yes, 1=read from keyboard)'
      READ(*,*,err=9) ksg
      if (ksg.eq.1) then
         write(*,*) 'Enter sigma-u, sigma-v for turbulence'
         READ(*,*,err=9) sigu, sigv
      else
         SIGU = 0.96 * U/ALOG(Z/Z0)
         SIGV = SIGU
      end if

10     continue
      write(*,*) 'Calculate turbulence length w/respect to'
      write(*,*) ' hub height? (0=yes, 1=read from keyboard)'
      READ(*,*,err=10) kel
      if (kel.eq.1) then
         write(*,*) 'Enter turbulence length scale for beta, alpha'
         READ(*,*,err=10) el1, el2
      else
         EL1 = 4.2 * Z
         EL2 = 0.4 * EL1
      END IF

11     continue

```

```

write(*,*) 'Calculate DT or NANGLE'
write(*,*) ' (0=NANGLE is known, 1=DT is known)'
READ(*,*,err=11) kindopt
if (kindopt.eq.0) then
  write(*,*) 'Enter number of divisions around'
  write(*,*) ' the disk for simulation'
  READ(*,*,err=11) nangle
  DT = 1.0 / (FLOAT(NANGLE) * EN0)
else
  write(*,*) 'Enter data discretization interval (sec)'
  READ(*,*,err=11) dt
  NANGLE = 0.01 + 1.0 / (DT * EN0)
end if

12  continue
write(*,*) 'Calculate using windowing (Hanning)'
write(*,*) ' (0=No, 1=Enter windowing factor)'
READ(*,*,err=12) kwindow
if (kwindow.ne.0) then
  write(*,*) 'Enter highest final value acceptable in'
  write(*,*) ' the autocorrelation function without'
  write(*,*) ' windowing (Hanning)'
  READ(*,*,err=12) CHK
end if

13  continue
write(*,*) 'Enter the seed for the pseudo-random'
write(*,*) ' number generator'
READ(*,*,err=13) dseed

k9 = 1
k12 = 1
k13 = 1
k14 = 1
k15 = 1
k16 = 1

15  continue
write(*,*) 'Enter the label for the run'
READ(*,*,err=15) kserial

c *** hardwire the options for Von Karmen and Spectral output.
kxifpr = 1
kvkpr = 1

c
c *** Open the logical units that are to be used in the program
c
open(unit=7,file='THEORY.DAT',status='new')
open(unit=9,status='SCRATCH',form='unformatted')
open(unit=10,file='THEORY.BRF',status='new')
open(unit=12,file='SERIES.DAT',status='new')

```



```

open(unit=13,status='SCRATCH',form='unformatted')
open(unit=14,status='SCRATCH',form='unformatted')
open(unit=15,file='UNBVNKR.dat',status='new')
open(unit=16,file='UNBSPEC.dat',status='new')

```

```

IF(.not.(MWIND.EQ.0.OR.KNDOPT.EQ.0)) then
  WRITE(7,1001)
  STOP
end if

```

```

PIENO = PI * ENO
KMAX = MMTA2
NHAR = MMT2
ALIAS = ILIAS
DTA = DT / ALIAS
DTND = DT * PIENO
DTAND = DTND / ALIAS
NANGLEA = NANGLE * ILIAS
IF(NANGLEA.GT.MMTA)NANGLEA = MMTA
IF(K15.NE.0) K9 = 1
CMMT = MMT
CMMTA = MMTA

```

```

*   The fundamental and Nyquist frequencies of the spectrum S(n) before
*   removal of high frequency.(highly aliased) part.

```

```

EN1 = 1.0 / (CMMT * DT)
EN1ND = EN1 / (PIENO)
EN2 = 0.5 / DT
EN2A = EN2 * ALIAS
EN2ND = EN2 / (PIENO)
EN2AND = EN2ND * ALIAS
FF = 1.0 / (CMMT * DT)

```

```

SIGU2 = SIGU * SIGU
SIGV2 = SIGV * SIGV
UST1 = 0.4 * U / ALOG(Z/Z0)
UST2 = SIGU / 2.4
USTAR2 = UST1 * UST2
USTAR = SQRT (USTAR2)

```

```

ALFA = RADIUS / EL2
OMEGA = TWOPI * ENO
BETA = U / (EL1 * OMEGA)

```

```

WRITE(7,*) KAWTER(KAWT)
WRITE(10,*) KAWTER(KAWT)
WRITE(7,1201) KSERIAL
WRITE(10,1201) KSERIAL

```

```

IF(KAWT.EQ.1.OR.KAWT.EQ.2) SIG2 = SIGU2
IF(KAWT.EQ.3) SIG2 = SIGV2
IF(KAWT.EQ.4.OR.KAWT.EQ.5) SIG2 = SIGU2

```

```

CALL RODAPRINT(7,1)
CALL RODAPRINT(10,1)

CHKSM = 3.0 * CHK

*      Set linearly spaced dimensionless frequencies.

      DO 21 I = 1, 80
        ENP(I) = 0.1 * FLOAT(I)
        ENLND(I) = ENP(I) / PI
        ENL(I) = ENLND(I) * PIENO
21      CONTINUE

      DO 22 I = 1, 20
        FI = I
        ENL1ND(I) = 0.05 * FI * ENLND(1)
        ENL1(I) = ENL1ND(I) * PIENO
22      CONTINUE
*      End initial section of program.

C*****
*      The steps from here to calculation of R(K) calculate the auto-
*      correlation function for a rotating point according to the memo
*      by J. R. Connell. The autocorrelation is a function of three
*      dimensionless parameters, ALFA, BETA, and T.
C*****

*      G43 is the gamma function for 4/3.
      G43 = 0.89298

      G13 = 3.0 * G43
      CONST = 2.0 / G13

***
*      Do VAWT simulation for u or v.
***
      IF(KAWT.EQ.2.OR.KAWT.EQ.3) CALL VAWTUV (R, KMAX, DTAND, ALFA,
*      BETA, CHKSM, KWINDOW, TWOARG, CHECK, PI, ENO, KAWT, CONST, TMAX)

***
*      Do VAWT simulation for tangential or normal component.
***
      IF(KAWT.EQ.4.OR.KAWT.EQ.5) CALL VAWTTN (R, KMAX, DTAND, ALFA,
*      BETA, CHKSM, KWINDOW, TWOARG, CHECK, PI, ENO, KAWT, CONST,
*      NANGLEA, TMAX)
      IF(KAWT.GT.1) GO TO 301

***
*      Do HAWT simulation.
***
      DO 23 KZ = 1, KMAX
        R(KZ) = 0.0
23      CONTINUE
      T = 0.0
      DO 25 K = 1, KMAX

```

```

*      T is the dimensionless time argument for the autocorrelation function.
      T = T + DTAND
      ARGA = ( ALFA * SIN ( T ) ) ** 2.
      ARGB = ( BETA * T ) ** 2
      ARG = SQRT ( ARGA + ARGB )
      TWOARG = 2.0 * ARG
      BK13 = 0.0
      BK23 = 0.0
C****
*      SUBROUTINE BESSEL will calculate a modified Bessel function of the
*      second kind of orders 1/3 and 2/3 provided that the argument is
*      not greater than 8. If the argument is greater than 8, the summation
*      used to calculate the Bessel function will not converge, and calcula-
*      of the autocorrelation function must be terminated. An autocorrela-
*      tion function terminated before it intrinsically converges may
*      transform into a spectrum with some values negative. The printed
*      autocorrelation function should be examined to assess whether
*      it converged or not.
C****
      IF (TWOARG.LE.8.0) THEN
        CALL BESSEL ( TWOARG,BK13, BK23, T )
      END IF
      DIFF = BK13 - ( BK23 * ARGA ) / ARG
      ARG3 = ARG ** .33333333333
      R(K) = CONST * ARG3 * DIFF
      if(k.lt.3)go to 25

*      Terminate the autocorrelation function if it has converged.
      CHECK = ABS(R(K)) + ABS(R(K-1)) + ABS(R(K-2))
      IF(CHECK.LT.CHKSM) GO TO 26
25  continue

*      Used only if the above loop runs KMAX times. Printed value of KMAX
*      should be noted.

      GO TO 27
26  KMAX = K
27  IF(.NOT.(KWINDOW.EQ.0)) THEN

*      Use Hanning window if convergence has not occurred, and if allowed by
*      option.

      RK = R(K-1)
      FMAX = KMAX
      DO 29 K = 1, KMAX
        FK = K
        R(K) = R(K) * (0.50 + 0.50 * COS (PI * FK/FMAX))
29  CONTINUE
      WRITE(7,2901) RK
      END IF
      TMAX = FLOAT(KMAX) * DTA
301 WRITE(7,3011)KMAX, TMAX

```

```

        IF(.NOT.(KMAX.GT.1000)) THEN
            WRITE(7,3012) (R(K),K=1, KMAX)
            GO TO 31
        END IF

        ISK = 1 + KMAX/1000
        HT1(1) = R(1)
        I = 2
        K = 1 + ISK

306    CONTINUE
        HT1(I) = R(K)
        I = I + 1
        K = K + ISK
        IF (K.LE.KMAX) GO TO 306

        I = I - 1
        WRITE(7,3071) ISK
        WRITE(7,3012) (HT1(K), K = 1, I)

*       Determine which warning should be printed out because of manner of
*       termination of acf.

31     CONTINUE
        IF(.NOT.(KWINDOW.NE.0)) THEN
            IFLAG = 0
            IF(TWOARG.GT.8.0) IFLAG = 1
            IF(CHECK.GT.CHKSM) IFLAG = IFLAG + 2
            IF(IFLAG.EQ.0) GO TO 315
            GO TO (311, 312, 313) IFLAG
311    CONTINUE
            WRITE(7,3111)
            GO TO 315
312    CONTINUE
            WRITE(7,3121) CHECK
            GO TO 315
313    CONTINUE
            WRITE(7,3111)
            WRITE(7,3121) CHECK

*       End correlation calculating section of program

C*****
*       Compute spectrum S(n) by Fourier transformation of the
*       autocorrelation function. Here enter the FFT.
C*****

315    CONTINUE
        END IF
        KMAX1 = KMAX + 1
        XTEND(1) = CMPLX (1.0, 0.0)

```

```

DO 32 J = 2, KMAX1
  XTEND(J) = CMPLX (R(J-1), 0.)
  K = MMTA - J + 2
  XTEND(K) = XTEND(J)
32  CONTINUE

MMTC = MMTA
CALL COOLEY (XTEND,-MMTC)
CALL COOLEY (XTEND, MMTC)
CALL COOLEY (XTEND, 0)

A = REAL(XTEND(1))
B = AIMAG(XTEND(1))
XIF1(1) = 2.0 * A * SIG2 * DTA

CCCC
*   This section defines parameter values to removed aliased spectra.
CCCC
NHAR1 = NHAR + 1

*   End parameter definitions.

NSUM = 0
VSUM = 0.
DO 33 J = 2, MMT2
  XIF1(J) = 2.0 * REAL(XTEND(J)) * SIG2 * DTA
  IF(XIF1(J).LT.0.0) NSUM = NSUM + 1
  VSUM = VSUM + XIF1(J)
33  CONTINUE

VSUM = VSUM * FF
WRITE(7,3301) VSUM
IF(.NOT.(NSUM.EQ.0)) THEN
  WRITE(7,3351) NSUM
  WRITE(*,3351) NSUM
END IF

*   Write S(n) from FFT of R(t) to disc.
IF(K9.NE.0) WRITE(9) FF, NHAR, (XIF1(I), I = 1, NHAR)

*   Compute S(n) version of Von Karman spectrum.

IF(KAWT.EQ.3.OR.KAWT.EQ.4) GO TO 351
DO 35 N = 1, NHAR
  FN = N
  EN = FN * FF
  ENVK = EN * EL1 / U
  XVK(N) = VKU(ENVK) * SIG2 / EN
  XVKA(N) = VKUA(ENVK) * SIG2 / EN
35  CONTINUE
GO TO 355

```

```

351 DO 352 N = 1, NHAR
      FN = N
      EN = FN * FF
      ENVK = EN * EL1 / U
      XVK(N) = VKV(ENVK) * SIG2 / EN
      XVKA(N) = VKVA(ENVK) * SIG2 / EN
352 CONTINUE

* Write von Karman spectra and frequencies to disc.
355 if (.not.(KVKPR.EQ.0)) then
      WRITE(7,3701)(XVKA(N), N = 1, NHAR)
    end if

    IF(.not.(K13.EQ.0)) then
      WRITE(13) NHAR, (XVK(N), N = 1, NHAR), (XVKA(N), N = 1, NHAR)
      REWIND 13
    end if

C****
* Compute spectrum S(n) by Fourier transformation of the autocorrelation
* function at evenly spaced
* Compute the upper limit wave number based on the Nyquist frequency
* and the frequency difference in the frequency vector ENL, which is
* 0.1 * EN0.
C****

NEF = 0.001 + 5.0 / (DT * EN0)
IF(NEF.GT.80) NEF = 80

DO 37 N = 1, NEF
  A = 0.5
  T = 0.0
  DO 36 K = 1, KMAX
    T = T + DTAND
    A = A + R(K) * COS(TWOPI * ENLND(N) * T)
36 CONTINUE
* Dimensional equivalent of DT is DT/PIEN0.
  SPECL(N) = 4.0 * SIG2 * A * DTA
37 CONTINUE

* Compute spectral density within lowest frequency band.

DO 42 N = 1, 20
  A = 0.5
  T = 0.0
  DO 41 K = 1, KMAX
    T = T + DTAND
    A = A + R(K) * COS(TWOPI * ENL1ND(N) * T)
41 CONTINUE
  SPECL1(N) = 4.0 * SIG2 * A * DTA
42 CONTINUE

```

```

*      Calculate length scale by integrating acf.

      A = 0.5
      DO 43 K = 1, KMAX
        A = A + R(K)
43      CONTINUE
      SCALEL = A * DTA * U

*      Calculate S(n) version of von Karman spectrum at NEF evenly spaced
*      frequencies.
      DO 48 N = 1, NEF
        ENVK = ENL(N) * EL1/U
        IF(.NOT.(KAWT.EQ.3.OR.KAWT.EQ.4)) THEN
          VKSPEC(N) = SIG2 * VKUA(ENVK) / ENL(N)
          GO TO 48
        END IF
        VKSPEC(N) = SIG2 * VKVA(ENVK) / ENL(N)
48      CONTINUE

*      Print out S(n) analysis from FFT.
      IF(.NOT.(KXIFPR.EQ.0)) THEN
        WRITE(7,7101) (XIF1(I), I = 1, NHAR)
      END IF

*      Print out S(n) analysis.

      WRITE(7,8001) NEF
      WRITE(7,8101)
      DO 85 I = 1, 40
        IP = I + 40
        WRITE(7,8501) ENL(I), ENP(I), SPECL(I), VKSPEC(I), ENL(IP),
*      ENP(IP), SPECL(IP), VKSPEC(IP)
85      CONTINUE

      WRITE(7,8601)
      WRITE(7,8611) (ENL1(I), I = 1, 20)
      WRITE(7,8621)
      WRITE(7,8631) (SPECL1(I), I = 1, 20)

*      Compute and print out sums needed to compute variance from S(n).

      A = 0.
      DO 87 I = 2, NEF
        A = A + SPECL(I)
87      CONTINUE
      B = 0.
      DO 88 I = 1, 20
        B = B + SPECL1(I)
88      CONTINUE

      WRITE(7,8801) A, B
      VAR = ENL(1) * (A + 0.05 * B)
      WRITE(7,8811) VAR

```

```

WRITE(10,8811) VAR
WRITE(7,8812) SCALEL

*   End spectrum computing section of program.
write(*,*) 'Spectrum computation finished...'

*   Compute variance (energy) in the 1P, 2P,.....6P bands, where for example,
*   the variance in the 1P band is found by integrating from the 6th through
*   the 15th evenly spaced S(n) harmonics. This is done for both the
*   rotational spectrum SPECL(N) and the von Karman spectrum VKSPEC(N). The
*   first loop ending on Lable 882 performs this integration at frequencies
*   below the 1P band.

      K = 1
      SUM = 0.05 * B
      SUMVK = VKSPEC(1)
      DO 882 I = 2, 5
        K = K + 1
        SUM = SUM + SPECL(K)
        SUMVK = SUMVK + VKSPEC(K)
882    CONTINUE

      PVAR(1) = SUM * 0.1 * ENO
      PRMS(1) = SQRT(PVAR(1))
      PVARVK(1) = SUMVK * 0.1 * ENO
      DO 885 J = 2, 7
        SUM = 0.
        SUMVK = 0.
        DO 883 I = 1, 10
          K = K + 1
          IF(K.GT.NHAR1) GO TO 884
          SUM = SUM + SPECL(K)
          SUMVK = SUMVK + VKSPEC(K)
883    CONTINUE
        PVAR(J) = SUM * 0.1 * ENO
884    PRMS(J) = SQRT(PVAR(J))
        PVARVK(J) = SUMVK * 0.1 * ENO
885    CONTINUE
      CALL RODAPRINT(7,2)
      CALL RODAPRINT(10,2)

      if (k16.ne.0) then
        WRITE(16,8851) ENO
        WRITE(16,8851) PVAR
        WRITE(16,8851) PVARVK
      end if

*   Calculate simulated data using harmonic analysis.

90    IGGUWOPT = 1
*   Generate rv between 0 and 1 with uniform probability density.
JTCPLZ = JTCPL

```



```

CALL GGUW (DSEED, JTCPLZ, IGGUWOPT, G1)
DO 91 I = 1, JTCPL
  G1(I) = TWOPI * G1(I)
91  CONTINUE
  XTEND(1) = (0., 0.)
DO 92 I = 2, JTCPL
  A = SQRT (0.5 * XIF1(I) * FF)
  THETA = G1(I)
  CR = A * COS(THETA)
  CI = A * SIN(THETA)
  XTEND(I) = CMPLX (CR, CI)
  K = MMT - I + 2
  XTEND(K) = CONJG(XTEND(I))
92  CONTINUE

CALL COOLEY (XTEND, - MMT)
CALL COOLEY (XTEND,  MMT)
CALL COOLEY (XTEND,  0)

*      These are the simulated data.

DO 93 J = 1, MMT
  D1(J) = REAL (XTEND(J))
93  CONTINUE

96  CONTINUE
*      Calculate first four moment of simulated data.

SUM = 0.
DO 961 I = 1, MMT
  SUM = SUM + D1(I)
961  CONTINUE
SUM = SUM / CMMT
DO 962 I = 1, MMT
  D1(I) = D1(I) - SUM
962  CONTINUE
DO 963 I = 1, 4
  SMOM(I) = 0.
963  CONTINUE

DO 964 I = 1, MMT
  A = 1.0
  DO 964 J = 1, 4
    A = A * D1(I)
    SMOM(J) = SMOM(J) + A
  CONTINUE
964  CONTINUE

DO 965 J = 1, 4
  SMOM(J) = SMOM(J) / CMMT
965  CONTINUE
SMOM(3) = SMOM(3) / SMOM(2)**1.5

```

```

SMOM(4) = SMOM(4) / SMOM(2)**2
SMOM(1) = SUM
DO 966 I = 1, MMT
    D1(I) = D1(I) + SUM
966 CONTINUE
*   Write simulated data to disc.
    write(*,*) 'Writing simulated data...'

    IF(.NOT.(K12.EQ.0)) THEN
*       This statement writes one file of turbulence-only data and, if
*       MWIND.NE.0, one file with mean wind included.
        WRITE(12,*) MMT, (D1(I), I = 1, MMT)
    END IF

*       Calculate spectrum of simulated data.
    XTEND(1) = CMPLX (D1(1), 0.0)
    DO 97 I = 2, MMT
        XTEND(I) = CMPLX (D1(I), 0.0)
97 CONTINUE
    MMTC = MMT
    CALL COOLEY (XTEND,-MMTC)
    CALL COOLEY (XTEND, MMTC)
    CALL COOLEY (XTEND, 0)
    FAC = 2.0 * DT / CMMT
*       XIF1(1) is really the times series mean in this case.
    XIF1(1) = REAL (XTEND(1)) / CMMT
    XIF1(JTCPL) = REAL (XTEND(JTCPL)) * REAL (XTEND(JTCPL)) * FAC
    VSUM = 0.
    DO 971 J = 2, MMT2
        IJ = MMT - J + 2
        AN1 = HALF * (XTEND(J) + CONJG (XTEND(IJ)))
        XIF1(J) = AN1 * CONJG(AN1) * FAC
        VSUM = VSUM + XIF1(J)
971 .CONTINUE

    VSUM = VSUM * FF
    PVAR2(1) = 0.
    LDO = 0.5 * ENO / FF
    DO 972 I = 2, LDO
        PVAR2(1) = PVAR2(1) + XIF1(I)
972 CONTINUE
    PVAR2(1) = PVAR2(1) * FF

    DO 974 K = 1, 6
        I1 = LDO + 1
        FK = K
        K1 = K + 1
        LDO = (FK + 0.5) * ENO / FF
        PVAR2(K1) = 0.
        DO 973 I = I1, LDO
            PVAR2(K1) = PVAR2(K1) + XIF1(I)
973 CONTINUE

```

```

          PVAR2(K1) = PVAR2(K1) * FF
974  CONTINUE

      WRITE(7,9751) PVAR2
      WRITE(10,9751) PVAR2
      LPRXIF1 = 5.0 + 2.0 * ENO / FF
      IF(LPRXIF1.GT.JTCPL) LPRXIF1 = JTCPL
      WRITE(7,9801) (XIF1(I), I = 1, LPRXIF1)
      WRITE(7,9811) VSUM
      WRITE(10,9811) VSUM
      WRITE(7,9812) SMOM(1), SMOM(2)
      WRITE(7,9821) SMOM(3), SMOM(4)
      WRITE(10,9821) SMOM(3), SMOM(4)
      WRITE(7,9841)

CCCC
*      Write S(n) from simulated data to disc, this is a second file.
*      IF(MWIND.NE.0) a third file is also written. This one has the series
*      mean value in XIF1(1).
CCCC
      IF(K9.NE.0) WRITE(9) (XIF1(I), I = 1, NHAR)
      REWIND 9

*      Write nS(n) from simulated data to disc.

      IF(K15.NE.0) CALL LOGBAND (10., K13, MWINDFLAG)
      IF(.NOT.(K14.EQ.0)) THEN

          DO 985 I = 1, MMT
              XTEND(I) = XTEND(I) / CMMT
985  CONTINUE

*      Write complex Fourier coefficients from harmonic analysis of
*      simulated data to file.

          WRITE(14) MMT, (XTEND(I), I = 1, MMT)
          REWIND 14
      END IF
      IF(.NOT.(MWIND.EQ.0)) THEN
          WRITE(7,9861)
          WRITE(10,9861)
          MWINDFLAG = 1
          CALL FOURALTER (D1, DT, ENO, ANGLE)
          WRITE(7,9862) ANGLE, DELAY
          FNAN = NANGLE
          FANGLE = ANGLE + DELAY
          OFFSET = FANGLE * FNAN / 360.
          IFFSET = 0.25 * FNAN - OFFSET
          WRITE(7,9863) OFFSET, IFFSET
          DO 987 I = 1, NANGLE
              FI = I - 1
              FQ = 2.0 * PI * FI / FNAN

```

```

        DCOS(I) = COS(FQ)
        DSIN(I) = SIN(FQ)
987    CONTINUE
        GO TO (989, 990, 992, 993, 993) KAWT
C *****
989    CALL HAWTMEAN (D1M, NANGLE, Z, RADIUS, U, Z0, MMT, IFFSET,
        *DSIN)
        GO TO 994
C *****
990    DO 991 I = 1, MMT
        D1(I) = D1(I) + U
991    CONTINUE
        WRITE(7,9911) U
        GO TO 999
C *****
992    WRITE(7,9921)
        GO TO 999
C *****
993    CALL VAWTTNMEAN (D1M, NANGLE, RADIUS, U, MMT, IFFSET, DCOS,
        *          DSIN, KAWT, ENO)
994    CONTINUE
        WRITE(7,9941) (D1M(I), I = 1, NANGLE)
        KSET = MMT / NANGLE
        WRITE(7,9942) KSET
        DO 995 K = 1, KSET
            KN = (K - 1) * NANGLE
            DO 995 I = 1, NANGLE
                D1(I+KN) = D1(I+KN) + D1M(I)
            CONTINUE
995    CONTINUE
        NSET1 = NANGLE * KSET + 1
        J = 0
        DO 996 I = NSET1, MMT
            J = J + 1
            D1(I) = D1(I) + D1M(J)
996    CONTINUE
        MWIND = 0
        GO TO 96
999    CONTINUE
END IF

```

STOP '--- End of program ---'

```

C *** *** *** *** *** ***
C *  FORMAT STATEMENTS *
C *** *** *** *** *** ***
1001 FORMAT(1H,'KNOPT MUST EQUAL 0 AND NANGLE MUST BE SPECIFIED
        * WHEN MWIND.EQ.1')
1201 FORMAT(1H,'SERIAL NUMBER ', A)
2901 FORMAT (1H,'Hanning WINDOW USED - LAST R BEFORE USE', F7.4)
3011 FORMAT(1H,' AUTOCORRELATION FUNCTION',I6,
        * ' steps',F10.2,' seconds')

```

```

3012 FORMAT ( 1X, 15F8.4 )
3071 FORMAT(1H , 'After first value skip interval is', I3)
3111 FORMAT(1H , 'WARNING - BESSEL FUNCTION DID NOT CONVERGE')
3121 FORMAT(1H , 'WARNING - ACF DID NOT CONVERGE, CHECK = ', E11.3)
3301 FORMAT(1H , 'VARIANCE FROM INTEGRATION OF ROTATIONAL
* S(M) COMPUTED BY FFT OF ACF', F12.6, ' (M/S)**2')
3351 FORMAT(1H , I5, ' NEGATIVE NUMBERS IN REDUCED FFT PRODUCED
* SPECTRUM - S(n)r.')
3701 FORMAT(1H , 'VON KARMAN S(N) SPECTRUM',
*/(1H , 5F12.6, F15.6, 4F12.6))
7101 FORMAT(1H , 'S(n) estimates from FFT of ACF',
*/(1H , 5F12.6, F15.6, 4F12.6))
8001 FORMAT(1H , 'S(n) analysis - ', I3, ' evenly spaced frequencies')
8101 FORMAT(1H , 'FREQUENCY(HZ) FREQUENCY(P) S(N) VKS(N) '
*11X, 'FREQUENCY(HZ) FREQUENCY(P) S(N) VKS(N) ')
8501 FORMAT(1H , F13.5, F14.1, 2F12.6, F24.5, F14.1, 2F12.6)
8601 FORMAT(1H , 'SPECTRAL DENSITY FOR 20 DIVISIONS OF LOWEST FREQUENCY
* BAND/' FREQUENCIES')
8611 FORMAT(1H , 10F12.6)
8621 FORMAT(1H , ' S(N) ')
8631 FORMAT(1H , 10F12.2)
8801 FORMAT(1H , 'SUMS OF S(N) FOR THE TWO SERIES', 2F12.2)
8811 FORMAT(1H , 'VARIANCE OF S(N) ON THIS PAGE, S(N)c',
*F10.4, ' (M/S)**2')
8812 FORMAT(1H , 'LENGTH SCALE FROM INTEGRATION OF ACF IS', F10.1 ' M')
8851 FORMAT(1H , F10.4, F15.4, 5F10.4)
9701 FORMAT(1H , 'MMT, MMT2, JTCPL, ENO, FF, FAC AT 9701',
*3I6, 2F10.4, E12.4)
9751 FORMAT(1H , 'VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
* SPECTRUM OF SIMULATED DATA, S(n)r', /1H , F10.4, F15.4,
*5F10.4)
9801 FORMAT(1H , 'SPECTRAL ESTIMATES FROM SIMULATED DATA',
*/'FIRST NUMBER IS SERIES MEAN', / (1H , 10F12.4))
9811 FORMAT(1H , 'VARIANCE OF S(N)r FROM SIMULATED DATA', F10.4)
9812 FORMAT(1H , 'SMOM(1), SMOM(2)', 2F10.4)
9821 FORMAT(1H , 'SKEWNESS AND KURTOSIS', 2F10.4)
9841 FORMAT(1H , 'HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED')
9861 FORMAT(1H , 'ANALYSIS OF SIMULATED DATA INCLUDING MEAN
* WIND EFFECT')
9862 FORMAT(1H , 'PHASE ANGLE FOR 1P IN SIMULATED DATA',
*F10.1, ' DEGREES', /1H , 'OFFSET ANGLE BETWEEN MEAN WIND
* AND TURBULENCE AT 1P (DELAY)', F10.1, ' DEGREES')
9863 FORMAT(1H , 'OFFSET, IFFSET, ' F10.1, I6)
9911 FORMAT(1H , 'THE MEAN WIND VALUE', F10.2, ' M/SEC HAS BEEN ADDED
* TO ALL SIMULATED WIND VALUES.')
9921 FORMAT(1H , 'THERE IS NO MEAN WIND ADDITION FOR THE V COMPONENT')
9941 FORMAT(1H , 'ONE CYCLE OF MEAN WIND EFFECT - M/S', / (1H , 20F6.2))
9942 FORMAT(1H , 'NUMBER OF COMPLETE MEAN WIND CYCLES IN SIMULATION', I6)

```

END

```

$ LARGE
SUBROUTINE BESSEL (X, BK13, BK23, TZ)
C
C   This subroutine calculates the summation for the modified
C   Bessel function of the second kind with orders 1/3 and 2/3.
C   The standard designation of  $K(1/3)(x)$  or  $K(2/3)(x)$ , as may be
C   seen, for example, on page 358 of C.R. Wylie: "Advanced Engineering
C   Mathematics" - 3rd edition. When on the UNIVAC or VAX this summation
C   converges to an acceptable value only if the argument x is 8 or less.
C   This is presumably due to roundoff or truncation errors.
C

REAL*8 F43, F53, G43, G53, G73, G83
*      , TW043, TW053, TW073, TW083
REAL*8 X43, X53, XSQ, X73, X83, SUM13, SUM23
*      , A13, A23
REAL*8 TP13, TM13, TP23, TM23, F13, F23, F73, F83

TOL = 0.00001
PI = 4 * ATAN(1.)
C13 = 0.5 * PI/SIN(PI/3.)
C23 = 0.5 * PI/SIN(2.0*PI/3.)
F13 = 1./3.
F23 = 2./3.
F43 = 4./3.
F53 = 5./3.
F73 = 7./3.
F83 = 8./3.

C
C *** Gamma function of 4/3
G43 = .8929797410964966
GS43 = G43

C
C *** Gamma function of 5/3
G53 = .9027454853057861
GS53 = G53

G73 = F43 * G43
G83 = F53 * G53
TW043 = 2.0**F43
TW053 = 2.0**F53
TW073 = 2.0**F73
TW083 = 2.0**F83
X43 = X**F43
X53 = X**F53
XSQ = X*X
X73 = X**F73
X83 = X**F83
SUM13 = 0.
SUM23 = 0.

```

```

C
C *** Index of summation
      AK = 1.0
      FK = AK
20    CONTINUE
C
C ***       $i^{1/3} J(-1/3)(ix) - i^{-1/3} J(1/3)(ix)$ 
      A13 = X53/(TW053*FK*G53) - X73/(TW073*FK*G73)
C
C ***       $i^{2/3} J(-2/3)(ix) - i^{-2/3} J(2/3)(ix)$ 
      A23 = X43/(TW043*FK*G43) - X83/(TW083*FK*G83)

      SUM13 = SUM13 + A13
      SUM23 = SUM23 + A23

      IF (.NOT.(ABS(A13).LT.TOL.AND.ABS(A23).LT.TOL)) THEN
        X43 = X43 * XSQ
        X53 = X53 * XSQ
        X73 = X73 * XSQ
        X83 = X83 * XSQ
        TW043 = 4.0 * TW043
        TW053 = 4.0 * TW053
        TW073 = 4.0 * TW073
        TW083 = 4.0 * TW083
        G43 = G43 * (AK + F13)
        G53 = G53 * (AK + F23)
        G73 = G73 * (AK + F43)
        G83 = G83 * (AK + F53)
        AK = AK + 1.0
        FK = FK * AK
        GO TO 20
      END IF

      TP13 = (X**F13)/((2.0**F13)*GS43)
      TM13 = (X**(-F13))/((2.0**(-F13))*1.5*GS53)
      TP23 = (X**F23)/((2.0**F23)*GS53)
      TM23 = (X**(-F23))/((2.0**(-F23))*3.0*GS43)
      SUM13 = SUM13 + TM13 - TP13
      SUM23 = SUM23 + TM23 - TP23

C
C ***  $K(1/3)(x)$ 
      BK13 = SUM13 * C13
C
C ***  $K(2/3)(x)$ 
      BK23 = SUM23 * C23

      RETURN
      END

```

```

$LARGE
      SUBROUTINE COOLEY(A,NN)
C      PCF CREATION DATE - 11 OCT 70, TIME 22.45.48
C      AUTHOR...JIM WINKELMAN, MODIFCATIONS FOR CDC 6600,MILT. SMITH
C      FAST FOURIER TRANSFORM FOR N=2**L
C      CALL THE SUBROUTINE FIRST WITH N=-MAX(N) TO BE USED
C      A IS THE COMPLEX ARRAY OF OBSERVATIONS AND IS REPLACED
C      WITH A SCRAMBLED COMPLEX ARRAY OF ANSWERS
C      CALL THE SUBROUTINE WITH N=0 TO UNSCRAMBLE THE ANSWER ARRAY
C      THE ARRAY TO BE UNSCRAMBLED MUST BE THE SAME SIZE AS THE
C      LAST ARRAY TRANSFORMED
C      REFERENCE..COOLEY-TUKEY, MATH OF COMP, APRIL 65,VOL 19 NO 90
C
C      INCLUDE 'RODASIM.INC/LIST'
$INCLUDE:'RODASIM.INC'
      COMPLEX W,A,X
      COMPLEX CSQRT
      DIMENSION A(*), W(MMTA2)
      IF(NN)1,3,2
1     N=-NN
      W(1)=(1.0,0.0)
      X=(0.0,1.0)
      K=1
11    DO 12 J=1,K
      M=J+K
12    W(M)=X*W(J)
      K=K+K
      X=CSQRT(X)
      IF((K+K).LT.N) GO TO 11
      RETURN
2     MM=NN
      N=NN
      L=1
23    M=MM/2
      I=1
      DO 21 K=1,N,MM
      MK=M+K-1
      DO 22 J=K,MK
      JM=J+M
      X=W(I)*A(JM)
      A(JM)=A(J)-X
22    A(J)=A(J)+X
21    I=I+1
      IF(M.LE.1) RETURN
      MM=M
      L=L+1
      GO TO 23
3     DO 31 J=2,N-1
      MSK = 1
      I = J-1
      K=0
      DO 33 II=1,L

```



```

      IM = IAND(I,MSK)
      IF(IM.GT.0)K = K+1
      IF(II.EQ.L)GO TO 33
      K = ISHFT(K,1)
      MSK = ISHFT(MSK,1)
33  CONTINUE
      K=K+1
      IF(K.LE.J) GO TO 31
      X=A(J)
      A(J)=A(K)
      A(K)=X
31  CONTINUE
      RETURN
      End

```

```

$LARGE
CCCC
C      This subroutine computes the Fourier cosine and sine coefficients
C      A(EN0) and B(EN0) for a given frequency EN0, prints out these coeffi-
C      cients and subtracts.
CCCC
      SUBROUTINE FOURALTER (D1, DT, EN0, ANGLE)
$INCLUDE:'RODASIM.INC'
      DIMENSION D1(*)
      REWIND 12
      READ(12,*) MMTZ, (D1(I), I = 1, MMTZ)
      IF(MMTZ.NE.MMT) GO TO 2
      PI = 3.14159265
      CMMT = MMT
      FAC = 2.0 * PI * EN0 * DT
      SUMA = 0.
      SUMB = 0.
      DO 1 I = 1, MMT
      FI = I - 1
      SUMA = SUMA + D1(I) * COS(FI * FAC)
1 SUMB = SUMB + D1(I) * SIN(FI * FAC)
      A = 2.0 * SUMA / CMMT
      B = 2.0 * SUMB / CMMT
      AMP = SQRT (A*A + B*B)
      ANGLE = 0.
      ANGLE = 180.0 * ATAN2(B, A) / PI
      WRITE(7,1001) A, B, AMP, ANGLE
1001 FORMAT(1H , 'A, B, AMP, ANGLE IN DEGREES', 4F10.4)
      GO TO 3
      2 WRITE(6,2001) MMT, MMTZ
2001 FORMAT(1H , 'MMT, MMTZ IN FOURALTER', 2I8,
      *' - ALTERATIONS NOT MADE')
      3 RETURN
      END

```

```

$ LARGE
      SUBROUTINE HAWTMEAN (D1M, NANGLE, Z, RADIUS, U, Z0, MMT,
* IFFSET, DSIN)
      DIMENSION DSIN(1), D1M(1)
      DENOM = ALOG (Z/Z0)
      DO 20 I = 1, NANGLE
      J = I + IFFSET
      IF(J.GT.NANGLE) J = J - NANGLE
      IF(J.LE.0) J = J + NANGLE
      Z1 = Z + RADIUS * DSIN(J)
      D1M(I) = U * ALOG(Z1/Z0) / DENOM
20 CONTINUE
      RETURN
      END

```

```

$ LARGE
CCCC
*      This program accepts two vectors of power spectra density,
*      SN1 and SN2, at evenly spaced frequencies and converts the to
*      NS(N) spectra at logarithmically spaced frequencies. The routine
*      is adopted from Program SPECM. This routine fills everything in
*      descending order of frequency. Therefore they are reversed in the
*      filed output.
CCCC
      SUBROUTINE LOGBAND (BPSD, K13, MWF)
$ INCLUDE: 'RODASIM.INC'
      DIMENSION SN(JTCPL,4), CBW(32), BW(64), IDF(32)
      DIMENSION ENSN(32,4), NTV(32), NLV(32)
      DIMENSION ENSNA(5,4), CBWA(5)
*      FF is fundamental frequency, 1/time length of record.
*      NHAR is number of harmonics in spectrum
*      SN(I,1) is spectrum from FFT of acf.
*      First SN(I,2) is spectrum of simulated data, turbulence, only.
*      It should be identical to SN(I,1).
*      Second SN(I,2) is spectrum of simulated data with mean wind effect
*      included.
*      Note that File 9 was rewound in main program, but not here.
      READ(9) FF, NHAR, (SN(I,1), I = 1, NHAR)
      READ(9) (SN(I,2), I = 1, NHAR)
      IF(MWF.NE.0) READ(9) (SN(I,2), I = 1, NHAR)
      NSPEC = 2
      IF(K13.EQ.0) GO TO 10
*      These are the original and altered forms of the von Karman spectrum,
*      respectively.
      READ(13) NHAR2, (SN(I,3), I = 1, NHAR2), (SN(I,4), I = 1, NHAR2)
      REWIND 13
      NSPEC = 4
10  BANDW = 1.0 / BPSD
*      This is the Nyquist frequency.
      FQQ = FLOAT(NHAR) * FF
      I = 0
16  I = I + 1
      FI = I
      CBW(I) = FQQ / 10.0**((FI-0.5)*BANDW)
      I2 = 2*I
      IM = I2-1
      BW(IM) = FQQ / 10.0**((FI-1.0)*BANDW)
      BW(I2) = FQQ / 10.0**(FI*BANDW)
      DIFF = BW(IM) - BW(I2)
      IF(DIFF.GT.FF) GO TO 16
      IBN = I - 1
      WRITE(7,1611) IBN, BPSD
1611 FORMAT(1H ,I3, ' LOGARITHMICALLY SPACED BANDS AT', F10.0,
* ' PER SPECTRAL DECADE')

```

```

        IF(IBN.LE.32) GO TO 20
        WRITE(7,1701) IBN
1701  FORMAT(1H , 'IBN TOO LARGE',I4)
        GO TO 90
    20  JBN = 2*IBN
        K = 0
        DO 30 I = 1, JBN, 2
            K = K + 1
            NT = 1.5 + BW(I) / FF
            NL = 1.5 + BW(I+1) / FF
            IF(NT.GT.NHAR) NT = NHAR
            IF(NL.GT.NHAR) GO TO 30
            NTV(K) = NT
            NLV(K) = NL
            NTMNL = NT - NL + 1
            IDF(K) = NTMNL
            DO 22 NS = 1, NSPEC
22      ENSN(K,NS) = 0.
            DO 25 J = NL, NT
                DO 25 NS = 1, NSPEC
25      ENSN(K,NS) = ENSN(K,NS) + SN(J,NS)
            DO 29 NS = 1, NSPEC
29      ENSN(K,NS) = CBW(K) * ENSN(K,NS) / FLOAT (NTMNL)
30  CONTINUE
        NLOW = NL - 2
        DO 35 N = 1, NLOW
            FN = N
            CBWA(N) = FF * FN
            DO 34 NS = 1, NSPEC
34      ENSNA(N,NS) = CBWA(N) * SN(N+1,NS)
35  CONTINUE
        WRITE(7,4001)
4001  FORMAT(1H , 'BANDED NSN SPECTRA')
        WRITE(7,4002)
4002  FORMAT(1H , 'BAND CENTER, HI, LOW (HZ), NS(N),
        * HARMONIC COUNT PER BAND [NS(N):ORIG',9X,'SIM',
        *10X,'VK',8X,'VKA]')
        DO 50 I = 1, IBN
            I2 = 2*I
            IM = I2 - 1
            50 WRITE(7,5001) CBW(I), BW(IM), BW(I2), IDF(I), NLV(I),
            *NTV(I), (ENSN(I,NS), NS = 1, NSPEC)
5001  FORMAT(1H ,3F12.5, 3I6, F16.5, 3F12.5)
        WRITE(7,5101)
5101  FORMAT(1H , 'UNBANDED NSN SPECTRA')
        WRITE(15,5501) NLOW
        DO 53 N = 1, NLOW
            WRITE(7,6001) CBWA(N), (ENSNA(N,NS), NS = 1, NSPEC)
            WRITE(15,6001) CBWA(N), (ENSNA(N,NS), NS = 1, 4)
53  continue

```

```
      WRITE(15,5501) IBN
5501  FORMAT(1H ,I10)
      DO 60 I = IBN, 1, -1
        60 WRITE(15,6001) CBW(I), (ENSN(I,NS), NS = 1, 4)
6001  FORMAT(1H ,5F12.6)
      90 RETURN
      END
```

```

$LARGE
      SUBROUTINE GGUBS (DSEED, N, R)
C
C   THIS SUBROUTINE WAS WRITTEN WITH THE SAME ALGORITHM THAT IS IN
C   IMSL.
C
C   DATE: 09-OCT-1987
C
      PARAMETER (TW031 = 2147483648.)
      PARAMETER (ISEV5 = 16807)
      INTEGER*4 N, I
      REAL*4 R(*)
      real*8 DSEED

      DO 10 I = 1,N
         DSEED = MOD((ISEV5*DSEED),(TW031-1.))
         R(I) = DSEED / TW031
10      CONTINUE
      RETURN
      END

      SUBROUTINE GGUW(DSEED, N, IOPT, R)
C
C   THIS SUBROUTINE WAS WRITTEN WITH THE SAME ALGORITHM THAT IS IN
C   IMSL.
C
C   DATE: 09-OCT-1987
C
      INTEGER*4 N, IOPT, I, idx, indx
      REAL*4 R(*), RND, WK(128)
      real*8 DSEED
      equivalence (indx, rnd)

C *** LOAD THE WORK ARRAY FOR LATER USE
      IF (IOPT.EQ.1) then
         do 1 i = 1,128
            wk(i) = 0.
1         continue
            CALL GGUBS(DSEED,128,WK)
         end if

C *** LOAD THE RANDOM NUMBER ARRAY
      DO 10 I = 1,N
         CALL GGUBS(DSEED,1,RND)
         idx = mod((indx/256),128) + 1
         R(I) = WK(IDX)
         WK(IDX) = RND
10      CONTINUE

      RETURN
      END

```

\$LARGE

SUBROUTINE RODAPRINT(LU, KP)

\$INCLUDE:'RODASIM.INC'

```
COMMON DT, DTA, DTND, DTAND, EN1, EN1ND, EN2,
*EN2A, EN2ND, EN2AND, NANGLE, NANGLEA, RADIUS, ENO, Z, U,
*ZO, KSG, SIGU, SIGV, EL1, EL2, KNDOPT,
*KWINDOW, CHK, KMAX, NHAR, USTAR, ALFA, BETA, SIGU2,
* SIGV2, PVAR(7), PRMS(7), PVARVK(7)
IF(KP.NE.1) GO TO 40
WRITE(LU,1001) RADIUS
1001 FORMAT(1H , 'RADIUS OF ROTATION', F6.1,
* ' M')
WRITE(LU,1051) ENO
1051 FORMAT(1H , 'RATE OF ROTATION', F11.4, ' HZ')
WRITE(LU,1101) Z, ZO
1101 FORMAT(1H , 'HUB HEIGHT', F14.1, ' M', /1H , 'SURFACE
*ROUGHNESS LENGTH', F10.4, ' M')
WRITE(LU,1151) U
1151 FORMAT(1H , 'MEAN WIND SPEED', F10.2, ' M/S')
WRITE(LU,1201) SIGU, SIGV
1201 FORMAT(1H , 'TURBULENCE RMS VALUES', /1H , 5X, 'U-COMPONENT',
*F10.3, ' M/S', /1H , 5X, 'V-COMPONENT', F10.3, ' M/S')
WRITE(LU,1301) SIGU2, SIGV2
1301 FORMAT(1H , 'TURBULENCE VARIANCES', /1H , 5X, 'U-COMPONENT',
*F10.3, ' (M/S)**2', /1H , 5X, 'V-COMPONENT', F10.3,
* ' (M/S)**2')
WRITE(LU,1401) USTAR
1401 FORMAT(1H , 'FRICTION VELOCITY', F9.3, ' M/S')
WRITE(LU,1501) EL1, EL2
1501 FORMAT(1H , 'TURBULENCE INTEGRAL LENGTH SCALES',
*/1H , 5X, 'LONGITUDINAL', F7.1, ' M',
*/1H , 5X, 'LATERAL', F7.1, ' M')
WRITE(LU,1601) MMT
1601 FORMAT(1H , 'NUMBER DATA TO BE SIMULATED', I5)
WRITE(LU,1701) DT
1701 FORMAT(1H , 'DISCRETIZATION INTERVAL ', F13.4, ' SEC')
WRITE(LU,1801) ILIAS
1801 FORMAT(1H , 'ALIAS FACTOR', I5)
DEG = 360./FLOAT(NANGLE)
WRITE(LU,1901) DEG
1901 FORMAT(1H , 'ANGULAR DISCRETIZATION INTERVAL', F7.1,
* ' DEGREES')
IF(KNDOPT.EQ.0) WRITE(LU,2001)
2001 FORMAT(1H , 'NANGLE WAS READ IN - DT WAS CALCULATED')
IF(KNDOPT.NE.0) WRITE(LU,2101)
2101 FORMAT(1H , 'DT WAS READ IN - NANGLE WAS CALCULATED')
WRITE(LU,2201) ALFA, BETA
2201 FORMAT(1H , 'ALFA, BETA', 2F12.4)
WRITE(LU,2301) KMAX, NHAR
2301 FORMAT(1H , 'LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION',
*I5, /1H , 'NUMBER OF HARMONICS IN SPECTRA', I19, /1H , 'This is
* also a comparison between number of harmonics in original
```



```

      * spectrum and reduced version.')
      WRITE(LU,2401) EN1
2401  FORMAT(1H , 'FUNDAMENTAL FREQUENCY IS',F12.6, ' HZ')
      WRITE(LU,2501) CHK
2501  FORMAT(/1H , 'MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT
      * WINDOWING', F8.5)
      IF(LU.NE.7) GO TO 50
      WRITE(LU,3001)
3001  FORMAT(1H , 'DIFFERENT FORMS OF VARIABLES:',
      */1H ,5X, '      - original',
      */1H ,5X, ' _A   - including extensions associated with alias
      * removal',/1H ,5X, ' ND - dimensionless variable',
      */1H ,5X, ' AND - both of the above')
      WRITE(LU,3101) DT, DTA, DTND, DTAND
3101  FORMAT(1H , 'DISCRETIZATION INTERVAL - DT',
      */1H ,5X, ' ',F9.3, ' SEC',/1H ,5X, ' A', F8.3, ' SEC',
      */1H ,5X, ' _ND',F7.3,/1H ,5X, ' _AND',F6.3)
      WRITE(LU,3201) MMT, MMTA
3201  FORMAT(1H , 'NUMBER OF SIMULATED DATA - MMT',
      */1H ,5X, ' ',I9,/1H ,5X, ' A',I8)
      WRITE(LU,3301) EN1, EN1ND
3301  FORMAT(1H , 'FUNDAMENTAL FREQUENCY - EN1'/1H ,5X,
      * ' ',F13.5, ' HZ',/1H ,5X, ' _ND',F11.5)
      WRITE(LU,3401) EN2, EN2A, EN2ND, EN2AND
3401  FORMAT(1H , 'NYQUIST FREQUENCY - EN2',
      */1H ,5X, ' ',F13.5, ' HZ',/1H ,5X, ' A',F12.5, ' HZ',
      */1H ,5X, ' _ND',F11.5,/1H ,5X, ' _AND',F10.5)
      WRITE(LU,3501) NANGLE, NANGLEA
3501  FORMAT(1H , 'NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE',
      */1H ,5X, ' ',I6,/1H ,5X, ' _A',I5)
      IF(KP.EQ.1) GO TO 50
40  CONTINUE
      IF(LU.EQ.7) WRITE(7,4101)
4101  FORMAT(1H , 'VARIANCES FOR FIRST HALF-P AND FOR 6P
      * FROM 80-MEMBER SPECTRUM'/1H , 'S(n)c, - (M/S)**2')
      IF(LU.EQ.10) WRITE(10,4111)
4111  FORMAT(1H , 'VARIANCES FOR FIRST HALF-P AND FOR 6P
      * FROM 80-MEMBER SPECTRUM'/1H , 'S(n)c, - (M/S)**2')
      WRITE(LU,4201) PVAR
4201  FORMAT(1H ,F10.4, F15.4, 5F10.4)
      WRITE(LU,4301) PRMS
4301  FORMAT(1H , 'RMS'/1H ,F10.4, F15.4, 5F10.4)
      WRITE (LU,4311)
4311  FORMAT(1H , 'SAME VARIANCES COMPUTED BY INTEGRATING THE
      * VON KARMAN SPECTRUM, SvK(n)ca')
      WRITE(LU,4201) PVARVK
50  RETURN
      END

```

\$LARGE

```
SUBROUTINE VAWTTN (R, KMAX, DT, ALFA, BETA, CHKSM,  
*KWINDOW, TWOARG, CHECK, PI, ENO, KAWT, CONST, NANGLE, TMAX)  
  DIMENSION R(*), BCOS(360), BSIN(360), ANGEL(360)  
  *   Set angles on rotation circle where direction cosines will be  
  *   computed. Store direction cosines (some of which are sines).  
  *   Do this first for the moving Point B, then for the fixed Point A.  
  
  ANGLEA = 0.5 * PI * FLOAT(KAWT - 3)  
  WRITE(7,1701) ANGLEA  
1701 FORMAT(1H , 'ANGLEA', F10.4)  
  ANGFAC = 2.0 * DT  
  DO 18 I = 1, NANGLE  
    FI = I - 1  
    ANG = ANGFAC * FI + ANGLEA  
    IF(ANG.GT.2.0*PI)ANG = ANG - 2.0 * PI  
    ANGEL(I) = ANG * 180. / 3.14159265  
    BCOS(I) = COS(ANG)  
18  BSIN(I) = SIN(ANG)  
    COSA = COS(ANGLEA)  
    SINA = SIN(ANGLEA)  
    WRITE(7,1811) COSA, SINA  
1811 FORMAT(1H , 'COSA, SINA', 2F10.3)  
    WRITE(7,1851)  
1851 FORMAT(1H , 'DIRECTION COSINES FOR MOVING POINT')  
  *   G43 is the gamma function for 4/3.  
    DO 19 KZ = 1, KMAX  
      R(KZ) = 0.0  
19  CONTINUE  
    T = 0.0  
      IB = 0  
    DO 25 K = 1, KMAX  
  
  *   T is the dimensionless time arguement for the autocorrelation function.  
  
  *   The following is derived on pages 30 and 31 of the notebook labeled  
  *   "Rotational Spectrum Problem" and written by David Powell.  
  
    T = T + DT  
      BT = BETA * T  
      SINT2 = (SIN(T))**2  
      ARG = BT*BT + ALFA * (ALFA + 2.0 * BT) * SINT2  
      ARG = SQRT(ARG)  
      TWOARG = 2.0 * ARG  
      BK13 = 0.0  
      BK23 = 0.0  
      IF ( TWOARG .LE. 8.0 ) THEN  
        CALL BESSEL ( TWOARG,BK13, BK23, T )  
      END IF  
      ABK23 = ARG * BK23  
  *   Hinze's normalized Q11 is CONST * ARG3 * DIFF11.  
  DIFF11 = (BETA * T / ARG)**2 * ABK23 + BK13 - ABK23
```

```

      SIN2T = SIN(2.0*T)
*      Hinze's normalized Q12 is CONST * ARG3 * DIFF12.
      DIFF12 = 0.5 * (ALFA * BETA * T / ARG * ARG) * SIN2T * ABK23
*      Hinze's normalized Q22 is CONST * ARG3 * DIFF22.
      DIFF22 = (ALFA * SIN2T / TWOARG)**2 * ABK23 + BK13 - ABK23
      IB = IB + 1
      IF(IB.GT.NANGLE) IB = 1
C      TORN = KAWT - 3
C      GO TO (235, 236) TORN
*      Multiplication by direction cosines - tangential wind component.
235 S11 = DIFF11 * COSA * BCOS(IB)
      S12 = DIFF12 * (SINA * BCOS(IB) + COSA * BSIN(IB))
      S22 = DIFF22 * SINA * BSIN(IB)
      GO TO 24
*      Multiplication by direction cosines - normal wind component.
C 236 S11 = DIFF11 * SINA * BSIN(IB)
C      S12 = - DIFF12 * (COSA * BSIN(IB) + SINA * BCOS(IB))
C      S22 = DIFF22 * COSA * BCOS(IB)

24 ARG3 = ARG ** .3333333333
*      Hinze's normalized Qab.
      R ( K ) = CONST * ARG3 * (S11 + S12 + S22)
      IF(K.LT.3) GO TO 25

*      Terminate the autocorelation function if it has converged.

      CHECK = ABS(R(K)) + ABS(R(K-1)) + ABS(R(K-2))
      IF(CHECK.LT.CHKSM) GO TO 26
25 continue
      GO TO 27
26 KMAX = K
27 IF(KWINDOW.EQ.0) GO TO 30
      RK = R(K-1)
      FMAX = KMAX
      DO 29 K = 1, KMAX
      FK = K
29 R(K) = R(K) * (0.50 + 0.50 * COS (PI * FK/FMAX))
      WRITE(7,2901) RK
2901 FORMAT (1H , 'Hanning WINDOW USED - LAST R BEFORE USE', F7.4)
30 TMAX = FLOAT(KMAX) * DT/(PI*ENO)
      RETURN
      END

```

\$LARGE

```
      SUBROUTINE VAWTTNMEAN (D1M, NANGLE, RADIUS, U, MMT, IFFSET,
*DCOS, DSIN, KAWT, ENO)
      DIMENSION D1M(*), DCOS(*), DSIN(*)
      PI = 3.141592654
      K3 = KAWT - 3
      GO TO (10, 30) K3
10  SPEED = 2.0 * PI * ENO * RADIUS
      DO 20 I = 1, NANGLE
      J = I + IFFSET
      IF(J.GT.NANGLE) J = J - NANGLE
      IF(J.LE.0) J = J + NANGLE
      D1M(I) = U * DSIN(J) + SPEED
20  CONTINUE
      GO TO 50
30  DO 40 I = 1, NANGLE
      J = I + IFFSET
      IF(J.GT.NANGLE) J = J - NANGLE
      IF(J.LE.0) J = J + NANGLE
      D1M(I) = U * DCOS(J)
40  CONTINUE
50  RETURN
      END
```

```

$ LARGE
SUBROUTINE VAWTUV (R, KMAX, DT, ALFA, BETA, CHKSM, KWINDOW,
* TWOARG, CHECK, PI, ENO, KAWT, CONST, TMAX)
INTEGER UORV
DIMENSION R(*)
UORV = KAWT - 1
DO 10 KZ = 1, KMAX
    R(KZ) = 0.0
10 CONTINUE
    T = 0.0
    DO 25 K = 1, KMAX

*       T is the dimensionless time argument for the autocorrelation function.

*       The following is derived on pages 30 and 31 of the notebook labeled
*       "Rotational Spectrum Problem" and written by David Powell.

        T = T + DT
        ARGB = BETA * BETA * T * T
        ARG = ARGB
        ARG = ARGB + ALFA * (1.0 - COS(2.0*T)) *
*         (BETA * T + 0.5 * ALFA)

CCC
C       The step below defines the "A" on page 31 of my notebook, where
C       "A" = r/2L. The step above obviously defines "A"***2, which
C       is derived before "A".
CCC
21      ARG = SQRT(ARG)
        TWOARG = 2.0 * ARG
        BK13 = 0.0
        BK23 = 0.0
        IF ( TWOARG .LE. 8.0 ) THEN
            CALL BESSEL ( TWOARG, BK13, BK23, T )
        END IF
        GO TO (235, 236) UORV
*       Hinze's normalized Q11 is CONST * ARG3 * DIFF.
235 DIFF = BK13 - BK23 * (ARG*ARG - ARGB)/ARG
        GO TO 24
236 YO2L = 0.5 * ALFA * SIN (2.0*T)
*       Hinze's normalized Q22 is CONST * ARG3 * DIFF.
        DIFF = BK13 - BK23 * (ARG*ARG - YO2L*YO2L)/ARG
24 ARG3 = ARG ** .333333333333
        R ( K ) = CONST * ARG3 * DIFF
        IF(K.LT.3) GO TO 25

*       Terminate the autocorelation function if it has converged.

        CHECK = ABS(R(K)) + ABS(R(K-1)) + ABS(R(K-2))
        IF(CHECK.LT.CHKSM) GO TO 26
25 continue
        GO TO 27
26 KMAX = K

```

```

27 IF(KWINDOW.EQ.0) GO TO 30
   RK = R(K-1)
   FMAX = KMAX
   DO 29 K = 1, KMAX
     FK = K
29  R(K) = R(K) * (0.50 + 0.50 * COS (PI * FK/FMAX))
   WRITE(7,2901) RK
2901 FORMAT (1H , 'Hanning WINDOW USED - LAST R BEFORE USE', F7.4)
30  TMAX = FLOAT(KMAX) * DT/(PI*ENO)
   RETURN
   END

```

```
PARAMETER (NEXP = 11)
PARAMETER (MMT = 2**NEXP)
PARAMETER (M2MT = 2 * MMT)
PARAMETER (MMT2 = MMT/2)
PARAMETER (ILIAS = 4)
PARAMETER (MMTA = ILIAS * MMT)
PARAMETER (MMTA2 = MMTA/2)
PARAMETER (JTCPL = 1 + MMT2)
```


APPENDIX B

SELECTED PORTIONS OF REPORT PNL-5857, DEFINING PARAMETERS
AND VARIABLES IN THE PNL THEORETICAL TURBULENCE SIMULATION CODE

APPENDIX B

SELECTED PORTIONS OF REPORT PNL-5857, DEFINING PARAMETERS AND VARIABLES IN THE PNL THEORETICAL TURBULENCE SIMULATION CODE

Here we reproduce Chapter 3, the glossary given in Appendix A, and Appendix D from a report by David Powell and James Connell, A Model for Simulating Rotational Data for Wind Turbine Applications (PNL-5857, published at the Pacific Northwest Laboratory, Richland, Washington, in April 1986). The report documents the model RODASIM1. The table of contents from the document is included here to illustrate the other material discussed in the report.

A MODEL FOR SIMULATING
ROTATIONAL DATA FOR WIND
TURBINE APPLICATIONS

D. C. Powell
J. R. Connell

April 1986

Prepared for the
U.S. Department of Energy
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Pacific Northwest Laboratory
Richland, Washington 99352

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3.0 DESCRIPTION OF PROGRAM AND USER'S GUIDE

The computer program is executed by submitting a prepared command file. This command file specifies numerous variables and options set by the user. The variables include both wind turbine and meteorological parameters. The read-in parameters are defined and discussed in the first section. The following section summarizes the operation of the program. The main program is treated first, and then the subroutines. Appendix A lists the code and provides a more complete glossary of program variables.

3.1 PARAMETERS TO BE READ IN

The parameters to be read in are organized in five groups, referred to as records. Each parameter has several optional values, described below. Units of the input physical parameters are mks.

3.1.1 First Record

KAWT: The option KAWT directs which of the following simulations will be performed:

- KAWT = 1: HAWT u
- 2: VAWT u
- 3: VAWT v
- 4: VAWT tangential (VAWT t)
- 5: VAWT radial (VAWT r).

MWIND: The program has the option of simulating either the total wind component, including the mean wind effect, or turbulence only, as determined by the value of MWIND.

- MWIND = 0: simulate turbulence only
- 1: simulate turbulence and mean wind effect.

DELAY: This is the phase delay, in degrees, imposed on the mean wind effect (mwe), modeled at the rotational frequency 1P. If DELAY is zero, the program is written so that the 1P harmonics of mwe and turbulence will be in phase. For any other value of DELAY, the mwe is delayed by that angle. Thus, the mwe DELAY would be incorporated as follows

$$U(t, mwe) = \phi(\omega \times t - \pi \times \text{DELAY}/180.)$$

where ϕ is either a sine or a cosine function.

One possible treatment for DELAY is to treat it as a random variable of even distribution. In this case, several runs could be made so that the statistical nature of the interrelation of mean flow and turbulence could be sampled. Another plausible scenario would be to read DELAY in as zero. This is a worst-case scenario for the HAWT u-component and the VAWT tangential component simulations, making the mwe and turbulence 1P effects occur in phase. A lesser variance is produced for the radial simulations when DELAY equals zero, since the radial turbulence is 90 degrees out of phase with the tangential turbulence, and therefore 90 degrees out of phase with the mean wind effect.

3.1.2 Second Record

The second record consists of physical parameters and related options.

RADIUS: This specifies the radius of rotation to be simulated.

ENO: This is the rate of rotation, in Hz, to be simulated.

Z: This is hub height.

U: This is the mean wind speed at height Z. $U(Z)$ will necessarily take on a value between the machine's cut-in and cut-out wind speeds.

Z0: Z0 is a length parameter invented exclusively for meteorological reasons. This is the surface roughness length. Surface roughness consists physically of such things as grasses, bushes, trees, buildings, and terrain features. The rougher the surface, the larger the value of Z0. It corresponds to no single factor that can be measured in nature. Since it cannot be measured, a value must be selected from a table of surface roughness values, such as those given by Chan et al. (1983) and by Panofsky and Dutton (1984). (The first is an engineering report, the second a meteorological book.) For a typical rural setting, gently rolling land with crops and a few trees, setting a Z0 value of 0.1 m is appropriate. The value of Z0 affects only the turbulence variance, not the shape of the spectrum.

KSG: This option determines whether the computer or the user provides values for SIGU and SIGV, the turbulence rms of the u- and v-components, respectively.

KSG = 0: The program calculates SIGU and SIGV.

1: The program accepts values of SIGU and SIGV as the next numbers read in.

There are uncertainties and inconsistencies to be recognized whether SIGU and SIGV are calculated or read in. The uncertainties arise from the fact that not all the physics necessary to model the low frequency part of the u and v turbulence spectra are known. Therefore, when these parameters are estimated using existing models, measured and modeled values may differ significantly. Since the rms is the square root of the frequency integral of the spectrum, these uncertainties are part of the calculated rms. In addition and for the same reason, a measured value may not be typical for the site at which it was measured.

The inconsistency comes from the fact that the von Karman theory on which this model is based assumes that SIGU equals SIGV. Actually, the von Karman theory is based on the theory of isotropic turbulence, which assumes that all variances of turbulence-directional components are equal. In the atmosphere, this is not true. It is more reasonable to assume that SIGV is about 0.8 SIGU. But if such values are used in the program, the high frequency portions of the spectra, which are well-known, will be out of the proper relationship to each other. This higher frequency range of the spectrum is where the harmonic spikes occur.

If the program is allowed to calculate SIGU and SIGV, it takes a conservative approach by setting them equal to each other. Thus, SIGV is set at the higher value appropriate for SIGU.

If measured values are supplied by the user, the values should be based on Eulerian data samples at least 10 minutes long and sampled at a discretization rate of no less than 5 samples per second. Otherwise the calculated variance will be too low. It can be corrected, but the correction depends on the current height and mean wind speed and requires good understanding of meteorological dimensionless turbulence spectra.

KEL: This option can have the following values:

KEL = 0: Program calculates EL1 and EL2.

= 1: Program accepts values of EL1 and EL2 as the next numbers read in.

The parameters EL1 and EL2 are the integral scales of u-component turbulence in the longitudinal and lateral directions, L_x and L_y , respectively. Numerically, they are of more uncertain evaluation than the rms values. These integral scales are more fully defined and described in Appendix C.

The character of the rotational spectra may be adjusted by manipulating values of EL1 and EL2 (Powell et al. 1985). In general, increasing L_y decreases the portion of the energy transferred to the spikes and decreases the peakedness. Increasing L_x increases the peakedness without significantly affecting the amount of energy transferred to the peaks. Therefore, increasing both length scales proportionally lowers the amount of energy transferred into the spikes without significantly changing the peakedness.

This completes the information on the second record. A simple procedure for determining values for this record is as follows:

Set RADIUS, ENO, and Z according to the machine specifications.

Set U at the assumed mean wind speed.

Set Z0 at 0.1 if terrain and building feature are of "average rural roughness." Make comparisons by setting Z0 at 0.3 and at 1.0 if greater roughness is estimated; make comparisons by setting Z0 at 0.03 and 0.01 if less roughness is estimated. Obtaining a table of surface roughness values will help in estimating Z0. Because individual runs with this model are very cheap, it is economical to try several alternatives to achieve the greatest accuracy.

For HAWT analysis, set KSG and KEL at zero.

For VAWT analysis, set KSG at zero and KEL at 1. Then set EL1 and EL2 at about 3.3 Z.

Remember that all units are mks.

3.1.3 Third Record

The parameters of the third read-in record are more manipulable. Before choosing values, the user must decide how many data he wants to simulate and at what discretization interval. The discretization interval is most easily specified indirectly, by specifying the number of samples per revolution. The following suggestions are made:

KNDOPT: This is an option that allows the user to specify the discretization interval either in angular units or in seconds.

KNDOPT = 0: This is the easiest option, because the program rather than the user makes the calculations.

KNDOPT must be set at zero if MWIND does not equal zero. That is, if the mwe is to be simulated, the model requires an integral number of samples about the rotational circle, specified by the integer NANGLE.

KNDOPT = 1: Discretization interval (DT) is read in directly. If this option is used, DT should be no greater than $1.0/(12. * ENO)$.

NANGLE: This is the number of sectors the sampling (discretization) divides the rotational circle into. Note that NANGLE is an integer. The minimum allowable value of NANGLE is twice the number of harmonics the analyst wishes to model, which would be at least four or five. Therefore, NANGLE must be at least eight or ten. Actually, a value of twelve or greater is recommended. If the value is twelve, sampling positions 30 degrees apart are simulated. The discretization interval in seconds (DT) is calculated from NANGLE and ENO. That is, $DT = 1/(NANGLE * ENO)$. NANGLE is used directly in the calculation of the autocorrelation function only if KAWT is four or five, i.e., if the simulation is of either the VAWT tangential component or the VAWT radial component. NANGLE is used only if KNDOPT equals zero.

DT: DT is the discretization, or sampling, interval in seconds. A read-in value of DT is used only if KNDOPT equals one. If KNDOPT equals zero, NANGLE is used.

MMT: This is the number of simulated data. It must be 2^N , where N is an integer. This is because the FFT method cannot handle any number of data other than 2^N . A problem arises because the number of rotational cycles simulated is more likely to be fractional than integral. Thus, when the spectrum of these data is computed, the energy that physically belongs to certain frequencies is diffused upward and downward among all frequencies. However, if enough rotational cycles are simulated, the fraction of energy diffused out of the 1P rotational band by this mathematical artifice will be small. Twenty cycles seem to be sufficient for this purpose. Therefore, we recommend that the product (MMT x DT x ENO), or, equivalently, the quotient MMT/NANGLE, should at least equal 20. Thus, MMT must be greater than $20/(DT \times ENO)$ or greater than $20 \times NANGLE$. The program requires the user to perform these calculations.

There are other considerations in setting MMT. Usually the spectrum $S(n)$ should be calculated to a minimum frequency on the order of 0.01 Hz to adequately model the low frequency part of the spectrum. To do so requires that MMT be no less than the order of $(100/DT)$.

A minimum value of 1024 is recommended for MMT (these considerations may indicate the need for a higher minimum). The speed of the model means that the greater economy resulting from selecting smaller values is not important. In addition, the product MMT x ILIAS, the next parameter, must not exceed 16384.

ILIAS: This parameter removes the high-frequency part of the spectrum calculated by Fourier transform of the autocorrelation function (acf). The low frequency portion of the spectrum remaining equals $1/ILIAS$. Thus:

- ILIAS = 1: none of the spectrum is removed. The high-frequency end will be severely aliased.
- = 2: the upper half of the spectrum is removed, leaving the lower frequency half.
- = 4: three-fourths of the spectrum is removed.

A value of 4 is recommended for ILIAS. The program will accordingly use a discretization interval DTA one-fourth of the original and will allow calculation of an acf four times as long as the maximum allowance specification. After the

spectral transform of this acf has been calculated, three-fourths of it will be discarded and the relatively unaliased remainder will be used for data simulation.

KWINDOW: This is an option allowing the use of the Hamming window (Blackman and Tukey 1958) to taper the end of the autocorrelation function. The tapered autocorrelation function is given by:

$$\begin{aligned} R(t) \text{ tapered} &= 0.5 R(t) + 0.5 R(t) \cos(\pi t/T), t \leq T, \\ &= 0, t > T. \end{aligned}$$

T is the time length of the function at the point where it converges according to the convergence criterion CHK, the next parameter read in. If this criterion is not met, T is the maximum time allowed for the acf. The limit on the number of members of R(t) is (MMT x ILIAS/2). Therefore, the limit on T is (DT x MMT x ILIAS/2). The algorithm uses the value of CHK such that the acf is deemed convergent when the the sum of the absolute values of the last three computed values of the function does not exceed 3 x CHK. KWINDOW values are as follows:

KWINDOW = 0: Hanning window is not used.

= 1: Hanning window is used whether acf was terminated by the convergence criterion or not. Otherwise the spectral transform may have a "beard" (a rapid frequency oscillation in the spectrum).

CHK: This is the convergence criterion discussed above. A reasonable value range for CHK is 0.001 to 0.01.

NP: This is the number of degrees of freedom used in the impulse response function when the simulated data are calculated by the convolution of Gaussian white noise with an impulse response function. NP may not exceed MMT/2. It may very well be about one-tenth that amount. As will be explained in Section 3.1.5, the method of calculation using Gaussian white noise is one of two options for calculating the final simulated data. Since the other option, based on harmonic analysis, is the preferred one, we have had little experience setting NP. When the other option is used, NP is ignored.

This completes the information on the third record. A reasonable set of values would be:

```
KNDOPT = 0
NANGLE = 24
MMT     = 1024
ILIAS   = 4
KWINDOW = 1
CHK     = 0.001
NP      (irrelevant if KBR in the fifth record has the recommended
         nonzero value).
```

Such a simulation requires about 20 to 45 seconds on the VAX 11/780, if an executable image of the code already exists.

3.1.4 Fourth Record

All of the options on this record govern writing to output files that are suitable for plotting by some other program. When they are set at any value other than zero, the specified task is done. Normally K8 and K14 are not used.

K8: Write the entire calculated impulse response function to disk.

K9: Write the following $S(n)$ spectra to disk:

- * the FFT transform of the autocorrelation function
- * the spectrum calculated from the simulated data.

K11: Write the $S(n)$ from cosine integration of the autocorrelation function to disk.

K12: Write the simulated data to disk.

K13: Write both the original and the altered von Karman $S(n)$ spectra to disk. (These alternatives will be explained below.)

K14: Write the complex Fourier coefficients of the transform of simulated data to disk.

K15: Calculate the logarithmically banded $nS(n)$ spectrum of simulated data and write it to disk, preceded by the unbanded $nS(n)$ values for the lowest three frequencies. (Banding is a smoothing procedure.)

3.1.5 Fifth Record

The last read-in record consists of further options.

KSERIAL: This is a five-character alphameric array used for naming a run.

KBR: This option governs the analytical method by which the simulated data are computed.

KBR = 0: Use convolution integral of Gaussian white noise and impulse response function.

= 1: Use spectrum for Fourier amplitudes and use random number generator to compute phases. This method is recommended.

KXIFPR, KVKPR: These are printing options for the unbanded estimates of the spectrum, as calculated by transformation of the autocorrelation function and for the von Karman spectrum, respectively. These spectra are not those of 80 frequencies from 0.1P to 8P. Rather, these are the 2^N harmonic estimates, where N may be 10 or 11. Therefore, the printouts can be quite large. Usually there is no need of them, as is explained below. Any nonzero value for these options results in printing.

3.2 FLOW CHART OF MAIN PROGRAM

Figure 6 is a flow chart of the main program. Subroutines are identified by names written in capital letters, in boxes having probes extending to other boxes. The abbreviation WDO stands for "written to disk by option." The option is usually one of the K* variables, such as K9. If the variable does not equal zero, the writing occurs.

3.3 SUMMARY OF PROGRAM OPERATION

Operation of the main program is summarized first, followed by the operations of specific routines.

3.3.1 Main Program

The user initiates the program by entering the parameters and variables as described in Section 3.1. The program then calculates autocorrelation functions, spectra and harmonic spike variances, and produces simulated data.

Flow Chart for Main Program RODASIM7

FIGURE 6. Flow Chart Illustrating Operation of the Main Program. $S(n)_d$ refers to the spectrum of the simulated data, it is numerically equivalent to $S(n)_r$.

3.3.1.1 Entering Parameters and Variables

First, the necessary parameter values are read in or determined internally. Then the two limit frequencies for certain of the calculated spectra are determined. The lowest frequency, EN1, is the inverse of the total time period of the simulated data. The highest frequency, EN2, is one-half the reciprocal of the sampling interval, DT.

At this point, other variables are identified by adding the letters A, ND, or AND to variable names already defined. The meanings are best illustrated by examples. Consider the variable DT, the discretization interval. The most direct way to create a spectrum reasonably free of aliasing is to create one with an extended high frequency range that is not needed and which is later disregarded. This is done by using a reduced discretization interval to compute the autocorrelation function of the rotational data. This reduced discretization interval is called DTA. It is computed by dividing DT by the alias reduction factor, ALIAS (the floating point version of ILIAS). Because the autocorrelation function is first computed in terms of dimensionless variables, we also need dimensionless equivalents of DT and DTA. These are DTND and DTAND, obtained by multiplying the corresponding dimensional variable by $(\pi \times EN0)$. Other modified variables exist in some or all of these forms for MMT, EN1, EN2, and NANGLE. Some of these additional values are defined for printing only. Others have an analytical role.

Once the initial variables are defined, Subroutine RODAPRINT is called to print out the initial variables.

3.3.1.2 Calculation of Autocorrelation Functions and of Several Spectra

The next section of the program calculates the autocorrelation function of the simulated data according to the specifications just read in and those just calculated. It calls on Subroutine BESSEL to calculate the modified Bessel functions of the second kind, $K(1/3)$ and $K(2/3)$. Then the logic in the main program uses the Bessel function values to determine the particular acf that corresponds to the value of KAWT read in, that is, HAWT u, VAWT u, etc. The discretization interval of the acf is DTAND.

If KAWT equals one (HAWT u-simulation), all of the acf calculation is done in the main program except the part done by Subroutine BESSEL. If KAWT is greater than 1, setting up one of the VAWT simulations, the entire acf calculation is performed in subroutines. Specifically,

if KAWT equals two or three (VAWT u or v simulation), Subroutine VAWTUV is used;

if KAWT equals four or five (VAWT tangential or radial simulation), Subroutine VAWTTN is used.

Subroutines VAWTUV and VAWTTN call Subroutine BESSEL at the appropriate point. The Hanning window adjustment is done in each of the VAWT subroutines as well as in the main program.

The next section of the program calculates several spectral functions. They may be easily confused with each other unless they are defined at the outset. These spectra are defined and described as follows:

$$S(n)_f, \text{ in } (m/s)^2/Hz.$$

This is the full spectrum calculated by submitting the acf to the fast Fourier transforms, FFT. These are performed by the Cooley-Tukey subroutine, called Subroutine COOLEY. The lowest value of n is EN1. The highest value is EN2A, or EN2 x ALIAS. The number of frequencies is MMT x ILIAS/2.

$$S(n)_r, \text{ in } (m/s)^2/Hz.$$

This is the reduced, relatively unaliased spectrum. It can be defined as

$$\begin{aligned} S(n)_r &= S(n)_f, \text{ if } n \text{ is not greater than the original EN2.} \\ &= 0, \text{ if } n \text{ is greater than the original EN2.} \end{aligned}$$

The lowest frequency is EN1; the highest frequency is EN2. The number of frequencies is MMT/2. $S(n)_f$ is never used after $S(n)_r$ is determined. $S(n)_r$ is the spectrum used as the basis for later data simulation.

$$S(n)_c, \text{ in } (m/s)^2/Hz.$$

This spectrum is computed by direct cosine integration of the acf for frequencies 0.1P, 0.2P,.....8.0P or EN2, whichever is lower. The maximum number of frequencies is 80.

$$S(n)_{c1}, \text{ in } (m/s)^2/Hz.$$

A detailed low frequency description analogous to $S(n)_c$, at 20 frequencies, is 0.005P, 0.010P....., 0.100P.

The following corresponding von Karman spectra are computed.

$$\begin{aligned} Svk(n)_r, & \text{ in } (m/s)^2/Hz - \text{ original von Karman spectrum analog of } S(n)_r, \\ Svk(n)_{ra}, & \text{ in } (m/s)^2/Hz - \text{ altered von Karman spectrum analog of } S(n)_r, \\ Svk(n)_{ca}, & \text{ in } (m/s)^2/Hz - \text{ altered von Karman spectrum analog of } S(n)_c. \end{aligned}$$

The term "ra" stands for the altered u- or v-spectra that were found to be the limit spectra of the rotational spectra, as rotational rate and radius (or rate alone) approach zero. This finding was not expected. More details and the analytical forms of the original and altered spectra are given in Appendix B. Both original and altered versions of the spectra are computed at this point and can be written to disk.

The von Karman spectra are computed according to which component simulation is being performed. The u-spectra are computed if the simulation is of HAWT u, VAWT u or VAWT t. The v-spectra are computed if the simulation is VAWT v or VAWT r. Most of these spectral functions can also be written to disk.

The spectra $S(n)_c$ and von Karman $Svk(n)_{ca}$ are printed out, along with the variance computed by integrating $S(n)_c$. At the bottom of the page, just above the variance, is a print-out of $S(n)_{c1}$ that was calculated for 20 divisions of the lowest frequency band, that is, from 0.005P to 0.100P. The reason for computing $S(n)_c$ is that both its numerical print-out and its plot make for very easy visual assessment of the rotational effect. $S(n)_c$ is a handy spectrum in this respect. The von Karman analogs, $Svk(n)_c$ and $Svk(n)_{ca}$, are printed and plotted for comparison of the rotational and corresponding Eulerian spectra.

3.3.1.3 Calculation of Harmonic Spike Variances

The next section of the program computes variances for the first six harmonic spikes of the rotational spectrum. This is the amount of energy per unit mass in each spike. The amount of energy in the von Karman spectrum in each of these frequency bands is also computed for comparison. These results are printed out. The spectra used in these computations are $S(n)_c$, $S(n)_r$, and $Svk(n)_{ca}$.

The reader should note at this point that since the $S(n)_r$ spectrum is used for data simulation, the $S(n)_c$ and its von Karman analogs $Svk(n)_c$ and $Svk(n)_{ca}$ are no longer necessary for the central purpose of the program. However, the $S(n)_c$ and $Svk(n)_{ca}$ spectra were the basis of earlier reported material (Powell et al. 1985) before the simulation capability was added to the code. For this reason, and because these spectra could conceivably be used to generate simulated data by the Gaussian white noise method, they have been retained.

3.3.1.4 Data Simulation

The remainder of the program performs the wind-speed time-series simulation by one of two alternative methods, according to the value given for the option KBR. The first method, used when KBR equals zero, calculates the simulated data by a convolution integration of Gaussian white noise with an impulse response function. The impulse response function is calculated from the spectrum $S(n)_r$ and can be written to disk. The result depends on an additional arbitrary input by the user, namely the number of degrees of freedom (members or NP), to be used in the calculated impulse response function. Increasing the number of members gets more of the spectral characteristics into the simulated data, at a cost of greater running expense. Experience is needed to determine what is an optimal number of members to use.

The computations we made by this method used about 50 members in the impulse response function. The spectrum of the simulated data differed somewhat from the original spectrum, and more than 20% of the original variance was lost. In contrast, when the second simulation alternative is used, the spectrum of the simulated data is identical with the original rotational spectrum, $S(n)_r$. Therefore, the two variances are also identical. There is no choice

to be made corresponding to what number of members of an impulse response function to use. For these reasons, we recommend the second alternative.

The second alternative, chosen when KBR equals one, uses the spectral estimates to calculate the amplitudes of the Fourier harmonics of the simulated data and to add the phase as an uncorrelated random variable from harmonic to harmonic. The random phase is provided by calling a routine that generates an evenly distributed random variable over the range 0 to 1 and scaling this over the range 0 to 2π .

Following either kind of simulation, several statistical calculations are made based on the simulated data. The variance, skewness and kurtosis of the simulated data are computed. Then the simulated data may be written to disk. Next, the power spectrum of the simulated data is computed. This is identical to the original power spectrum if the second simulation alternative was used or if the mwe has not yet been added in (see Figure 6). The computation of variance in the first half-P and in the harmonic spikes is repeated, this time using the spectrum of the simulated data. The spectrum and the Fourier coefficients it was computed from may be written to disk. The last computation, also optional, is a conversion of the $S(n)$ spectrum of the simulated data at evenly spaced frequencies to an $nS(n)$ spectrum at logarithmically spaced frequencies. There are ten bands per frequency decade. The $nS(n)$ estimates for the lowest frequencies are left unbanded. This is because banding has no advantages when the ratio between successive frequencies of the unbanded spectrum is greater than the frequency ratio within the specified band width. The $nS(n)$ version of the von Karman spectrum is also computed if the original version was written to disk.

The program terminates here if MWIND is zero, i.e., if no mwe simulation is to be made. Otherwise, the following operations are performed:

First, Subroutine FOURALTER is called to find the phase angle of the 1P harmonic in the simulated data D1. The ANGLE is identified by

ANGLE = Arctan (B, A), in degrees, where the equation of the mwe is

$$U[mwe](t) = A \cos(\omega \times t) + B \sin(\omega \times t)$$

or

$$U[mwe](t) = C \cos(\omega \times t - \pi \times \text{ANGLE}/180.),$$

where

$$C = \sqrt{A^2 + B^2}$$

and ω is the rotational rate in radians per second.

The calculated variables OFFSET and IFFSET are a combination designed to bring $U[mwe](t)$ into phase with the 1P turbulence harmonic when DELAY is zero, and when the mwe equations are written as they are in Subroutines HAWTMEAN and VAWTTNMEAN. The program calls up the appropriate subroutine to calculate one cycle of mwe for the particular HAWT or VAWT component simulation being calculated. This does not occur for either the VAWT u- or VAWT v-component simulations.

The one cycle of mwe is returned to the main program. It is extended through as many cycles as are needed to cover the turbulence. It is then added to the turbulence.

With this done, the program goes back to the moment-calculating routine and recalculates all the statistics of the simulated data. These include the moments, spectrum and harmonic spike integrations of the spectrum of the simulated data including mwe.

3.3.2 Specific Subroutine Operations

A selection of the following subroutines is called by each run. Figure 6 illustrates where the subroutines fit in the operation of the whole program.

3.3.2.1 Subroutine BESSEL

Subroutine BESSEL computes a summation for each of the Bessel functions until both addends are reduced below a certain tolerance. At this point, the

computed sums become the two Bessel function values, and control returns to the main program. The argument going into the summation begins near zero. When the argument exceeds eight, the sums diverge. Therefore, if the argument reaches eight, control is returned to the main program, and a warning message is printed out. Fortunately, this potential problem does not seem to exist in actual computations.

Of the four arguments in the call list, three are essential. The fourth applies only in the so-called D-line output used for checking the subroutine. The three essential arguments are the single input argument for the two Bessel functions and the two output values.

3.3.2.2 Subroutines VAWTUV and VAWTTN

These subroutines are alternate routes for the main program, depending on the value of KAWT, that is, on what kind of simulation is being executed. If the simulation is any of the VAWT simulations, the part of the main program that computes the acf for the HAWT simulation is bypassed and one of these subroutines is called. Subroutine VAWTUV is used for a VAWT u- or v-component simulation and Subroutine VAWTTN is used for a VAWT tangential or radial component simulation. Both of these subroutines have the same call to Subroutine BESSEL and the same windowing option as the main program has for the HAWT simulation. The call lists are somewhat long. Most of the variables therein are defined in the glossary in Appendix A. Ordinarily, the user need not be concerned with them.

3.3.2.3 Subroutine COOLEY

This FFT subroutine was authored by Winkelman and Smith before 1970. It accepts two real data series as the real and imaginary parts of a complex series and performs the FFT of the complex series. Certain additional logic is necessary to sort out the values for the two power spectra and the cross spectra when two sets of original data are entered, filling both the real and the imaginary parts of the complex series seen by the subroutine. In the present operations, we filled only the real slots.

The subroutine is called three times to effect the transform. There are two input variables. The first is the complex data series. The second is an indicator that differs on each of the three submissions:

1. the negative of the number of members in the complex data vector
2. the positive of the same number
3. zero.

The output Fourier transform values occupy the same slots the original data occupied.

3.3.2.4 Subroutine LOGBAND

This subroutine reads in a number of evenly banded $S(n)$ spectra over the same frequency range and converts them to $nS(n)$ spectra logarithmically banded. This operation is performed on $S(n)_r$, and on the von Karman spectra $Svk(n)_r$ and $Svk(n)_{ra}$, if they have been calculated and written to disk. The call list for the subroutine consists of

BPSD	number of logarithmically-spaced frequency bands per spectral decade. The recommended value of BPSD is 10.
K13	the option governing whether the von Karman spectra are written to disk.
MWF	a flag telling the subroutine whether or not to read a third record of $S(n)$ values. This third spectrum is of simulated data including mwe.

After the subroutine reads the $S(n)$ input spectra, it constructs the bounds of the logarithmically spaced bands. The highest frequency band has the Nyquist frequency ($0.5/DT$) for its upper bound. Upper bounds of the successively lower frequency bands are all related by the same ratio, which is

$$RATIO = 10.0^{(1.0/BPSD)}.$$

That is, if the upper bound of the highest band is FQQ , the Nyquist frequency, the lower bound of this band is $FQQ/RATIO$, and the central frequency is the geometric mean of those two. The second highest band has $FQQ/RATIO$ for its upper frequency bound and $FQQ/RATIO^2$ for its lower bound. This formation of frequency bands continues until the frequency band width becomes less than the

fundamental frequency, thus leaving some of the lowest frequency values of $S(n)$ unbanded. Once the band limits are established, the $nS(n)$ values are computed by straightforward arithmetic. The subroutine prints out a table of the banded estimates and, below these, the unbanded $nS(n)$ values are also printed out.

This feature was used to generate the spectra shown in Appendix B. Genuine rotational spectra would be distorted by this type of banding. Therefore, operation of Subroutine LOGBAND is not essential.

3.3.2.5 Subroutine FOURALTER

Given a frequency ENO , Subroutine FOURALTER computes the A and the B of the 1P wave:

$$S(1P)\text{turbulence} = A \cos(2\pi \times ENO \times t) + B \sin(2\pi \times ENO \times t) .$$

These are printed out, and the phase angle

$$\text{ANGLE} = \text{Arctan} (B, A)$$

is computed and returned to the main program so that the mean wind effect, which is a wave with frequency 1P, can be adjusted to the proper phase relation with the 1P wave of the turbulence.

3.3.2.6 Subroutines HAWTMEAN and VAWTTNMEAN

These subroutines calculate one cycle of simulated mean wind effect. Then this cycle is transferred to the main program and added repeatedly to the turbulence until enough cycles, including partial cycles, have been added to cover the turbulence record. Subroutine HAWTMEAN simulates the mwe for HAWT rotation; Subroutine VAWTTNMEAN simulates the mwe for either the tangential or the radial component of VAWT rotation.

3.4 ON BRACKETING THE ANSWERS BY ENVELOPING INPUT PARAMETERS

As indicated above, turbulence rms and length scales are uncertain. The turbulence rms during unstable conditions may well be 50 percent greater than

the program-calculated value, which applies for neutral conditions. Similarly, the effective surface roughness length may well be anywhere from $2/3$ to $3/2$ that reasonably assumed. Surface roughness length affects model calculations only through the rms. The results described in the next section suggest that both length scales specified by the model may be about 3.5 times the height. However, turbulence length scales do not scale exactly with height. Therefore, a wider range should be considered. The user may wish to submit a series of runs, varying parameter values within these ranges and plotting all results in order to get an envelope.

A reasonable envelope for rms would be 0.8 to 1.5 times the program-calculated values for SIGU. This allows for uncertainty about both atmospheric stability and surface roughness. However, if the stable atmosphere is to be modeled, the rms may well be half the program-calculated values. An envelope of values for rms can be used without running the model again because all simulated wind values are directly proportional to rms and all spectral values are directly proportional to the square of the rms. Other reasonable envelopes would be:

$$L_x: 3Z \text{ to } 6Z.$$

$$L_y: 0.4 L_x \text{ to } 1.0 L_x.$$

For HAWT simulations, a smaller choice of $L_y(u)$ is appropriate. For VAWT simulations, L_y should approximate L_x more closely. Calculating an envelope of values for L_x and L_y requires running the model for each individual pair of specified values.

A.2 GLOSSARY

The following listing describes the commonly used variables in the program. Variables not listed are in one of three categories: 1) working or temporary variables defined and used within a small segment of the program, 2) generalized loop indices, or 3) modifications of basic variables, indicated by names ending with A, ND, or AND (see Section 3.3.1.1).

One helpful aspect of the glossary is that it gives the units of all variables. Of course, this depends on the units of such input variables as height and mean wind speed. The program assumes that lengths are in meters and times in seconds. Dimensionless variables are labeled 'dmls.'

SCALARS

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
ALFA	Blade radius/turbulence length scale L_y .	dmls.	
ALIAS	Floating point ILIAS, alias reduction factor.	dmls.	
ANGLE	Phase angle of 1P harmonic in simulated data. Zero value indicates a cosine wave.	deg	
BETA	Blade rotation rate/(mean wind speed x turbulence length scale L_x).	dmls.	
BK13	Value of modified Bessel function of 2nd kind, $K(1/3)$.	dmls.	BESSEL
BK23	Same as above, but for $K(2/3)$.	dmls.	BESSEL
CHECK	Criterion for declaring acf convergent.	dmls.	
CHK	Read-in tolerance level defining convergence of acf.	dmls.	
CMMT	Floating point MMT.	dmls.	

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
DSEED	Parameter used in IMSL routine for generating uncorrelated random values evenly spaced from zero to one.	dmls.	
DT	Discretization interval for simulated data.	sec	
EL1	Longitudinal integral length scale for u-component turbulence, L_x .	m	
EL2	Lateral integral length scale for u-component turbulence, L_y .	m	
EN	Dimensional frequency argument for von Karman spectrum.	Hz	
EN0	Blade rotation rate.	Hz	
EN1	Fundamental frequency of data: reciprocal of total time span.	Hz	
EN2	Nyquist frequency of spectrum $S(n)_r$, and the spectrum of simulated data.	Hz	
ENVK	Dimensionless frequency for von Karman spectrum.	dmls.	
FAC	Time factor converting Fourier squared amplitudes to the one-sided spectral density $S(n)$.	sec	
FF	Fundamental frequency of spectral densities $S(n)_f$, $S(n)_r$, $Svk(n)_r$.	Hz	
ILIAS	Alias reduction factor. [If ILIAS = 4, 1/4 of the power spectrum $S(n)_f$, calculated from FFT of acf, is retained as $S(n)_r$.]	dmls.	
JTCPL	1. Index of the last member of acf as it is entered into the FFT process.		

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
JTCPL (cont'd.)	<p>2. Index of last member of $S(n)_r$ as it is entered into FFT process to compute impulse response function. Smaller value than above if ILIAS is greater than 1.</p> <p>3. Index of last value of $S(n)$ for simulated data. (Same value as in 2.)</p> <p>4. Index of last value of random phase used to calculate simulated data. (Same value as in 2.)</p>	dmls.	.
K8	Option to write impulse response function to disk.		
K9	Option to write $S(n)_r$ and spectrum of simulated data to disk. These spectra have half as many degrees of freedom as the simulated data have.		
K11	Option to write 80-member spectrum $S(n)_c$, (0.1P, 0.2P...8P) and corresponding altered von Karman spectrum to disk.		
K12	Option to write simulated data to file.		
K13	Option to write von Karman spectra, original and altered, to file. These spectra have half as many degrees of freedom as the simulated data have.		
K14	Option to write complex Fourier coefficients of transform of simulated data to file.		
K15	Option to calculate banded $nS(n)$ spectra for simulated data; also does so for the von Karman spectra stored if K13 does not equal zero.		.

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
KAWT	Simulation choice option: 1) HAWT u-component 2) VAWT u-component 3) VAWT v-component 4) VAWT tangential component 5) VAWT radial component.		
KBR	Option for calculation method for simulated data: 0) Convolution integral of impulse response function with Gaussian white noise. 1) Fourier transform of amplitudes from spectral harmonics and random phase.		
KEL	Option for length scales EL1 and EL2: 0) Let program calculate them. 1) Read them in.		
KMAX	Maximum number of members allowed in acf.		
KNDOPT	Option governing specification of discretization interval: 0) Specify angular value in degrees. 1) Specify time value in seconds.		
KSERIAL	Alphameric serial number for run, five characters.		
KSG	Option for SIGU and SIGV. 0) Let program calculate them, isotropically. 1) Read them in.		
KWINDOW	Option to multiply acf by Hamming window values. 0) Do not use window. 1) Use window.		

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
MMT	Number of simulated data. MMT must be 2^N , where N is an integer.		
NANGLE	Discretization interval in terms of number of angular divisions of rotational circle.	dmls.	
NDG	Number of degrees of freedom in Gaussian white noise.	dmls.	
NEF	Number of frequencies used in spectra $S(n)_c$ and corresponding von Karman spectra where frequency spacing interval is 0.1P.	dmls.	
NHAR	Number of harmonics (degrees of freedom) in spectrum $S(n)_r$ and corresponding von Karman spectra. (NHAR = MMT/2.)	dmls.	
NP	Arbitrary number of points to be used on one side of the two-sided impulse response function, not counting central value at zero argument.	dmls.	
OMEGA	Blade rotation rate.	radians/sec	
PI	3.141592654	dmls.	
RADIUS	Radius of rotation, blade radius.	m	
SIG2	SIGU2 or SIGV2, as is appropriate. If SIGU and SIGV are calculated internally, they are equal.	$(m/s)^2$	
SIGU	Rms of u-component turbulence.	m/s	
SIGU2	Variance of u-component turbulence.	$(m/s)^2$	
SIGV	Rms of v-component turbulence.	m/s	
SIGV2	Variance of v-component turbulence.	$(m/s)^2$	
T	Dimensionless running time used in calculation of acf and in the cosine integration of the acf to obtain $S(n)_c$.	dmls.	

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
THETA	Angle argument in phase angle vector.	radians	
TMAX	Length of acf in seconds.	sec	
TWOARG	Argument of calculated Bessel functions.	dmls.	
U	Mean wind speed at height Z.	m/s	
USTAR	Friction velocity.	m/s	
USTAR2	Square of friction velocity.	(m/s) ²	
VAR	Variance from integrating $S(n)_c$.	(m/s) ²	
VSUM	1. Variance from integrating $S(n)_r$, 2. Variance from integrating $S(n)_r$ of simulated data.	(m/s) ² (m/s) ²	
Z	Simulated wind turbine hub height.	m	
Z0	Surface roughness length.	m	

ARRAYS

D1(I)	Final simulated wind data.	m/s	
D1M(I)	One cycle of simulated mean wind effect.	m/s	
ENL(N)	80 linearly spaced frequencies at interval of 0.1P for spectral density SPECL(N).	Hz	
ENL1(N)	20 linearly spaced frequencies at interval of 0.005P for spectral density SPECL1(N).	Hz	
ENP(N)	Same as ENL(N) but numbered in P units (harmonics), i.e., 0.1, 0.2,....8.0.	P	
G1(I)	Gaussian white noise vector of unit variance.	dmls.	
HT1(I)	Two sided impulse response function. Mathematically, this is $h(t)\Delta t$ where $h(t)$ is a true impulse response function.	m/s	

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub-routine</u>
KAWTER(C)*30	Alphameric array indicating type of simulation.		
PRMS(M)	Square root of PVAR(M).	m/s	
PVAR(M)	Variance in each of the harmonic spikes of the rotational spectrum. PVAR(1) is variance of first 0.5P; PVAR(2) is variance of first spike, etc. This version is calculated by integrating SPECL(N).	(m/s) ²	
PVARVK(M)	Variances found by integrating over corresponding frequency ranges of von Karman spectrum.	(m/s) ²	
PVAR2(M)	Same as PVAR(M) but calculated by integrating XIF1(N).	(m/s) ²	
R(T)	Autocorrelation function incorporating rotational feature.	dm1s.	
RP(TS)	Evenly spaced subset of values from R(T) selected for printing convenience. RP is not used analytically.	dm1s.	
SMOM(4)	Mean, variance, skewness, kurtosis of simulated data.		
SPECL(N)	Spectral density at 80 frequencies, 0.1P, 0.2P...8.0, of simulated data. SPECL is calculated by direct cosine integration of R(T).	(m ² /s)	
SPECL1(N)	Same as SPECL(N) but for the 20 frequencies (0.005, 0.01.....0.1)P.	(m ² /s)	
VKSPEC(N)	Von Karman spectrum for same frequencies as SPECL(N).	(m ² /s)	
XIF1(N)	Spectral density S(n) calculated by FFT of R(T), where fundamental frequency is reciprocal of time length of data set.	(m ² /s)	

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>	<u>Sub- routine</u>
XTEND(K)	Input complex vector for FFT.		
XVK(N)	Von Karman spectrum corresponding to XIF1.	(m ² /s)	
XVKA(N)	Altered von Karman spectrum corresponding to XIF1.	(m ² /s)	

APPENDIX D

SAMPLES OF OUTPUT

The types of output we illustrate here are rotational spectra and simulated time series data. These results were generated using the following set of input parameters. The machine parameters are known to be appropriate for the VAWT but not for the HAWT. However the same input data were used for both, for the purpose of comparing model output. The parameters are:

Radius of Rotation	8.3 m
Rate of Rotation	1.0000 Hz
Hub Height	16.7 m
Mean Wind Speed	10.00 m/s
Turbulence RMS Values	
u-Component	1.652 m/s
v-Component	1.652 m/s
Turbulence Variances	
u-Component	2.729 (m/s) ²
v-Component	2.729 (m/s) ²
Friction Velocity	0.688 m/s
Turbulence Integral Length Scales	
Longitudinal	70.1 m
Lateral	28.1 m
Number of Data to be Simulated	1024
Discretization Interval	0.0417 s
Alias Factor	4
Angular Discretization Interval	15.0 degrees

Figure D.1 compares the turbulence spectra of the simulated HAWT u-component and the simulated VAWT u-component. Both spectral density $S(n)$ and the logarithmic spectrum $nS(n)$ are shown. It should be emphasized that the mean wind effect has been omitted in each case. If it had been included, the 1P spike would have been higher in both spectra, considerably higher for the

FIGURE D.1. Rotational HAWT u- and VAWT u-Spectra.
a. $S(n)$; b. $nS(n)$

VAWT u-spectrum. Clearly, however, the effect of turbulence alone in the u-component on the rotationally sampled spectrum of wind is more severe for the VAWT than for the HAWT, i.e., more severe on the horizontal circle than on the vertical circle.

Similar plots for the four VAWT simulations (u, v, tangential and radial) are shown in Figure D.2. Interesting features of this figure are:

1. At low P , the VAWT radial simulation has the strongest peaks.
2. At higher P , only the two u simulations maintain a distinct harmonic spike structure (see Figure D.1).

FIGURE D.2. Rotational Spectra $S(n)$ and $nS(n)$ for the Four VAWT Simulations
a. $S(n)$; b. $nS(n)$

In both Figure D.1 and Figure D.2, the $S(n)$ spectra are the 80-frequency spectra $S(n)_c$. The $nS(n)$ spectra are made by banding the $S(n)_r$ spectral estimates in eight evenly spaced bands.

The turbulence variances for the five runs are given in Table D.1. The spectra $S(n)_r$ and $S(n)_c$ are defined in Section 3.3.1.2.

The theoretical Eulerian turbulence variance for all cases is $2.73 (m/s)^2$. The variances above are less because the total length of the simulated time series is only 43 seconds, rather than the 10 or 15 minutes that is required to attain the theoretical variance from field data.

TABLE D.1. Variances of the Five Simulations, in $(\text{m/s})^2$

	$S(n)_r$	Integration of $S(n)_c + S(n)_{c1}$
HAWT u	2.17	2.41
VAWT u	2.26	2.54
VAWT v	2.41	2.35
VAWT t	2.53	2.48
VAWT r	2.45	2.72

Simulated data for VAWT u-component and VAWT radial component turbulence are shown in Figure D.3. The simulated wind speed time series are derived from these spectra. The graphs illustrate turbulence only. The changing mean wind effect is not included because it would mask the turbulence. The difference in the character of these stationary data over a short period is evident.

The variances in the first five harmonics for each type of simulation are shown in Figure D.4. One graph, D.4.a, compares the spike variances for the HAWT u and VAWT u simulations; the other, D.4.b, compares the spike variances for all four VAWT simulations. The energy in the first spike of the VAWT u simulation is greater than that in the first spike of the HAWT u simulation. However, the greatest differences are between the VAWT tangential and radial simulations on one hand, and the three other simulations on the other.

FIGURE D.3. Simulated Turbulence Data. a. VAWT u-Components; b. VAWT radial component

APPENDIX C

SAMPLE OUTPUT FROM THE FILE SUMMARY.DAT FOR THE
HAWT CASE AT HALF-BLADE RADIUS

HAWT SIMULATION
 SERIAL NUMBER HT050
 RADIUS OF ROTATION 9.5 M
 RATE OF ROTATION .8670 HZ
 HUB HEIGHT 30.5 M
 SURFACE ROUGHNESS LENGTH .0500 M
 MEAN WIND SPEED 10.00 M/S
 TURBULENCE RMS VALUES
 U-COMPONENT 1.497 M/S
 V-COMPONENT 1.497 M/S
 TURBULENCE VARIANCES
 U-COMPONENT 2.241 (M/S)**2
 V-COMPONENT 2.241 (M/S)**2
 FRICTION VELOCITY .824 M/S
 TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 120.1 M
 LATERAL 51.2 M
 NUMBER DATA TO BE SIMULATED 2048
 DISCRETIZATION INTERVAL .0937 SEC
 ALIAS FACTOR 4
 ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
 ANGLE WAS READ IN - DT WAS CALCULATED
 ALFA, BETA .1854 .0186
 LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
 NUMBER OF HARMONICS IN SPECTRA 1024
 THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
 SPECTRUM AND REDUCED VERSION.
 FUNDAMENTAL FREQUENCY IS .005211 HZ

 MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
 DIFFERENT FORMS OF VARIABLES:
 - ORIGINAL
 -A - INCLUDING EXTENSIONS ASSOCIATED WITH ALIAS REMOVAL
 -ND - DIMENSIONLESS VARIABLE
 -AND - BOTH OF THE ABOVE
 DISCRETIZATION INTERVAL - DT
 .094 SEC
 -A .023 SEC
 -ND .196
 -AND .049
 NUMBER OF SIMULATED DATA - MMT
 2048
 -A 8192
 FUNDAMENTAL FREQUENCY - EN1
 .00521 HZ
 -ND .00249
 NYQUIST FREQUENCY - EN2
 5.33600 HZ
 -A 21.34400 HZ
 -ND 2.54848
 -AND 10.18592
 NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE
 16
 -A 64
 HANNING WINDOW USED - LAST R BEFORE USE .0010
 AUTOCORRELATION FUNCTION 3440 STEPS 80.58 SECONDS

AFTER FIRST VALUE SKIP INTERVAL IS 4

.9121	.7492	.6424	.5636	.5050	.4630	.4352	.4201	.4170	.4258	.4484	.4802	.5283	.5924	.6722
.7525	.7697	.7029	.6203	.5500	.4953	.4552	.4283	.4134	.4099	.4174	.4361	.4659	.5088	.5565
.6081	.6455	.6489	.6163	.5656	.5137	.4691	.4345	.4105	.3968	.3930	.3988	.4138	.4375	.4682
.5026	.5342	.5539	.5539	.5339	.5012	.4646	.4307	.4029	.3828	.3709	.3670	.3710	.3824	.4000
.4221	.4454	.4654	.4767	.4755	.4619	.4393	.4130	.3875	.3657	.3495	.3394	.3358	.3384	.3466
.3594	.3752	.3912	.4043	.4112	.4096	.3906	.3832	.3638	.3444	.3274	.3144	.3061	.3028	.3043
.3102	.3195	.3307	.3420	.3508	.3551	.3534	.3457	.3335	.3187	.3038	.2904	.2800	.2732	.2702
.2710	.2752	.2819	.2900	.2900	.3041	.3068	.3051	.2991	.2896	.2783	.2666	.2560	.2476	.2420
.2393	.2397	.2426	.2475	.2534	.2592	.2634	.2651	.2635	.2587	.2513	.2423	.2331	.2246	.2178
.2131	.2108	.2109	.2129	.2165	.2208	.2250	.2280	.2290	.2275	.2236	.2177	.2106	.2032	.1964
.1908	.1869	.1849	.1847	.1862	.1888	.1920	.1950	.1971	.1977	.1963	.1931	.1883	.1826	.1767
.1711	.1666	.1634	.1616	.1613	.1623	.1642	.1665	.1687	.1702	.1705	.1693	.1666	.1627	.1581
.1533	.1488	.1450	.1423	.1408	.1404	.1411	.1425	.1442	.1458	.1468	.1469	.1458	.1436	.1404
.1366	.1327	.1290	.1259	.1236	.1223	.1219	.1223	.1233	.1246	.1258	.1265	.1264	.1255	.1236
.1210	.1179	.1147	.1116	.1091	.1072	.1060	.1058	.1058	.1066	.1075	.1083	.1088	.1087	.1078
.1063	.1041	.1015	.0989	.0964	.0942	.0926	.0916	.0912	.0914	.0919	.0925	.0931	.0934	.0933
.0925	.0912	.0894	.0873	.0851	.0830	.0812	.0799	.0790	.0787	.0787	.0790	.0795	.0799	.0801
.0799	.0793	.0782	.0767	.0749	.0731	.0714	.0699	.0687	.0680	.0678	.0676	.0679	.0682	.0685
.0686	.0684	.0678	.0669	.0656	.0642	.0627	.0612	.0600	.0590	.0584	.0580	.0580	.0581	.0584
.0586	.0586	.0584	.0579	.0571	.0561	.0549	.0536	.0524	.0514	.0505	.0500	.0497	.0496	.0497
.0499	.0500	.0500	.0498	.0493	.0487	.0478	.0468	.0457	.0448	.0439	.0432	.0427	.0424	.0424
.0424	.0425	.0426	.0425	.0423	.0420	.0414	.0407	.0398	.0390	.0381	.0374	.0368	.0364	.0362
.0361	.0361	.0361	.0362	.0361	.0359	.0356	.0351	.0345	.0338	.0331	.0324	.0318	.0313	.0310
.0307	.0306	.0306	.0307	.0307	.0306	.0304	.0302	.0297	.0292	.0287	.0281	.0275	.0270	.0266
.0262	.0261	.0260	.0259	.0259	.0259	.0259	.0257	.0255	.0251	.0247	.0242	.0237	.0232	.0228
.0225	.0222	.0220	.0219	.0219	.0219	.0219	.0218	.0217	.0215	.0212	.0208	.0204	.0200	.0196
.0192	.0189	.0187	.0186	.0185	.0184	.0184	.0184	.0183	.0182	.0180	.0178	.0175	.0172	.0168
.0165	.0162	.0159	.0157	.0156	.0155	.0155	.0155	.0154	.0154	.0153	.0151	.0149	.0147	.0144
.0141	.0138	.0136	.0134	.0132	.0131	.0130	.0130	.0129	.0129	.0128	.0128	.0126	.0125	.0122
.0120	.0118	.0115	.0113	.0112	.0110	.0109	.0109	.0108	.0108	.0108	.0107	.0106	.0105	.0104
.0102	.0100	.0098	.0096	.0094	.0093	.0092	.0091	.0090	.0090	.0090	.0089	.0089	.0088	.0087
.0086	.0085	.0083	.0081	.0080	.0078	.0077	.0076	.0075	.0075	.0075	.0074	.0074	.0074	.0073
.0072	.0071	.0070	.0069	.0067	.0066	.0065	.0064	.0063	.0062	.0062	.0062	.0061	.0061	.0061
.0060	.0059	.0059	.0058	.0056	.0055	.0054	.0053	.0052	.0052	.0051	.0051	.0051	.0050	.0050
.0050	.0049	.0049	.0048	.0047	.0046	.0045	.0044	.0044	.0043	.0042	.0042	.0042	.0041	.0041
.0041	.0041	.0040	.0040	.0039	.0038	.0038	.0037	.0036	.0036	.0035	.0035	.0034	.0034	.0034
.0033	.0033	.0033	.0033	.0032	.0032	.0031	.0031	.0030	.0029	.0029	.0028	.0028	.0028	.0027
.0027	.0027	.0027	.0027	.0026	.0026	.0026	.0025	.0025	.0024	.0024	.0023	.0023	.0023	.0022
.0022	.0022	.0022	.0022	.0021	.0021	.0021	.0021	.0020	.0020	.0019	.0019	.0019	.0018	.0018
.0018	.0018	.0017	.0017	.0017	.0017	.0017	.0017	.0016	.0016	.0016	.0015	.0015	.0015	.0015
.0014	.0014	.0014	.0014	.0014	.0014	.0013	.0013	.0013	.0013	.0013	.0012	.0012	.0012	.0012
.0011	.0011	.0011	.0011	.0011	.0011	.0011	.0011	.0010	.0010	.0010	.0010	.0010	.0010	.0009
.0009	.0009	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0008	.0008	.0008	.0008	.0008	.0007
.0007	.0007	.0007	.0007	.0007	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0006	.0006	.0006
.0006	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0004
.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0004	.0003	.0003
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001
.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

VARIANCE FROM INTEGRATION OF ROTATIONAL S(M)
 COMPUTED BY FFT OF ACF 1.910270 (M/S)**2
 VON KARMAN S(N) SPECTRUM

74.909900	55.000400	38.878940	28.095860	21.037690	16.297410	12.998020	10.620640	8.854138	7.506222
8.453985	5.618299	4.938014	4.380638	3.916657	3.528003	3.193743	2.908588	2.681872	2.446850
2.258207	2.091707	1.943941	1.812139	1.694030	1.587738	1.491898	1.404601	1.325348	1.252998
1.186754	1.125929	1.069934	1.018258	.970456	.928140	.884970	.846849	.810912	.777525
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.007859	.007838	.007818	.007797	.007777	.007756	.007736	.007716	.007696	.007676
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S(N)	ESTIMATES	FROM FFT OF	ACF						
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1.822746	2.105644	2.438888	2.830301	3.284480	3.793217	4.311327	4.726986	4.890339	4.727174
4.311614	3.793511	3.284742	2.830523	2.439075	2.105802	1.822886	1.582574	1.378011	1.203420
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.032768	.032896	.033017	.033132	.033239	.033338	.033430	.033512	.033587	.033652
.033707	.033753	.033789	.033814	.033830	.033836	.033830	.033815	.033789	.033752
.033705	.033648	.033581	.033504	.033417	.033320	.033215	.033100	.032977	.032846
.032706	.032560	.032406	.032246	.032079	.031907	.031729	.031547	.031360	.031189
.030975	.030778	.030578	.030376	.030172	.029968	.029763	.029557	.029351	.029146
.028942	.028739	.028537	.028338	.028141	.027946	.027755	.027566	.027381	.027200
.027022	.026849	.026680	.026516	.026357	.026203	.026054	.025910	.025771	.025638
.025511	.025389	.025273	.025163	.025059	.024961	.024868	.024782	.024702	.024628
.024559	.024497	.024441	.024390	.024346	.024307	.024273	.024246	.024224	.024208
.024198	.024190	.024190	.024194	.024203	.024217	.024235	.024258	.024285	.024317
.024352	.024391	.024433	.024479	.024528	.024579	.024634	.024691	.024751	.024812
.024876	.024941	.025007	.025074	.025142	.025211	.025280	.025350	.025419	.025488
.025556	.025623	.025689	.025754	.025817	.025878	.025937	.025994	.026048	.026100
.026148	.026194	.026236	.026274	.026309	.026340	.026367	.026389	.026408	.026422
.026431	.026436	.026437	.026432						

S(N) ANALYSIS - 80 EVENLY SPACED FREQUENCIES

FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)	FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)
.06670	.1	1.479231	5.062953	2.73470	4.1	.104298	.010685
.13340	.2	.193635	1.628942	2.80140	4.2	.077222	.010264
.20010	.3	.071300	.832057	2.86810	4.3	.055244	.009869
.26680	.4	.043599	.515859	2.93480	4.4	.042298	.009498
.33350	.5	.037932	.355874	3.00150	4.5	.037103	.009149
.40020	.6	.046719	.262713	3.06820	4.6	.038082	.008820
.46690	.7	.083761	.203233	3.13490	4.7	.044163	.008510
.53360	.8	.227145	.162705	3.20160	4.8	.054114	.008216
.60030	.9	.949734	.133718	3.26830	4.9	.064564	.007939
.66700	1.0	4.890336	.112190	3.33500	5.0	.069339	.007676
.73370	1.1	.949862	.095717	3.40170	5.1	.064457	.007427
.80040	1.2	.227452	.082799	3.46840	5.2	.053794	.007190
.86710	1.3	.084377	.072461	3.53510	5.3	.043354	.006965
.93380	1.4	.047952	.064043	3.60180	5.4	.036146	.006752
1.00050	1.5	.040512	.057087	3.66850	5.5	.032749	.006548
1.06720	1.6	.049249	.051266	3.73520	5.6	.032799	.006355
1.13390	1.7	.082040	.046340	3.80190	5.7	.035627	.006170
1.20060	1.8	.173658	.042130	3.86860	5.8	.040139	.005994
1.26730	1.9	.414342	.038500	3.93530	5.9	.044465	.005825
1.33400	2.0	.787738	.035345	4.00200	6.0	.046247	.005664
1.40070	2.1	.414518	.032585	4.06870	6.1	.044250	.005511
1.46740	2.2	.174058	.030154	4.13540	6.2	.039600	.005363
1.53410	2.3	.082753	.028001	4.20210	6.3	.034500	.005222
1.60080	2.4	.050382	.026084	4.26880	6.4	.030551	.005087
1.66750	2.5	.041946	.024368	4.33550	6.5	.028420	.004957
1.73420	2.6	.047751	.022827	4.40220	6.6	.028129	.004833
1.80090	2.7	.069409	.021435	4.46890	6.7	.029320	.004713
1.86760	2.8	.115783	.020174	4.53560	6.8	.031318	.004598
1.93430	2.9	.192950	.019028	4.60230	6.9	.033152	.004487
2.00100	3.0	.250870	.017983	4.66900	7.0	.033830	.004381
2.06770	3.1	.193085	.017027	4.73570	7.1	.032873	.004279
2.13440	3.2	.118040	.016149	4.80240	7.2	.030659	.004180
2.20110	3.3	.089717	.015342	4.86910	7.3	.028063	.004085
2.26780	3.4	.047806	.014597	4.93580	7.4	.025883	.003994
2.33450	3.5	.040585	.013909	5.00250	7.5	.024561	.003905
2.40120	3.6	.043421	.013271	5.06920	7.6	.024192	.003820
2.46790	3.7	.055529	.012679	5.13590	7.7	.024611	.003738
2.53460	3.8	.077246	.012127	5.20260	7.8	.025446	.003658
2.60130	3.9	.104276	.011614	5.26930	7.9	.026203	.003581
2.66800	4.0	.118884	.011134	5.33600	8.0	.026422	.003507

SPECTRAL DENSITY FOR 20 DIVISIONS OF LOWEST FREQUENCY BAND
FREQUENCIES

.003335	.006670	.010005	.013340	.016675	.020010	.023345	.026680	.030015	.033350
.036685	.040020	.043355	.046690	.050025	.053360	.056695	.060030	.063365	.066700
S(N)									
63.32	55.95	48.26	36.55	28.25	21.77	16.88	13.23	10.49	8.42
8.82	5.59	4.62	3.85	3.23	2.73	2.32	1.99	1.71	1.48

SUMS OF S(N) FOR THE TWO SERIES 13.31 335.45
 VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.0063 (M/S)**2
 LENGTH SCALE FROM INTEGRATION OF ACF IS 73.7 M
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM
 S(N)C, - (M/S)**2
 1.1418 .5034 .1501 .0763 .0477 .0334 .0251

RMS

1.0686 .7095 .3875 .2762 .2185 .1828 .1585
 SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
 .5600 .0832 .0237 .0119 .0074 .0051 .0037

VARIANCES FOR FIRST HALF-P AND FOR 8P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R

1.1059 .4441 .1489 .0763 .0478 .0336 .0253
 SPECTRAL ESTIMATES FROM SIMULATED DATA
 FIRST NUMBER IS SERIES MEAN

.0000	59.6109	45.0039	30.6520	20.4117	13.8403	9.6474	6.9124	5.0726	3.8026
2.9029	2.2527	1.7738	1.4154	1.1435	.9343	.7719	.6441	.5427	.4615
.3959	.3425	.2986	.2624	.2322	.2069	.1855	.1673	.1517	.1384
.1268	.1167	.1079	.1002	.0934	.0874	.0820	.0772	.0730	.0691
.0657	.0625	.0597	.0572	.0549	.0528	.0509	.0492	.0476	.0462
.0450	.0438	.0428	.0419	.0411	.0404	.0398	.0393	.0388	.0385
.0382	.0380	.0379	.0379	.0379	.0381	.0383	.0386	.0390	.0394
.0400	.0407	.0414	.0423	.0433	.0444	.0456	.0470	.0486	.0502
.0521	.0542	.0565	.0590	.0618	.0649	.0683	.0720	.0762	.0808
.0859	.0915	.0978	.1047	.1125	.1211	.1307	.1415	.1536	.1671
.1823	.1994	.2187	.2406	.2653	.2933	.3251	.3613	.4026	.4499
.5040	.5661	.6376	.7200	.8152	.9256	1.0539	1.2033	1.3779	1.5824
1.8227	2.1056	2.4389	2.8303	3.2845	3.7932	4.3113	4.7270	4.8903	4.7272
4.3116	3.7935	3.2847	2.8305	2.4391	2.1058	1.8229	1.5826	1.3780	1.2034
1.0540	.9257	.8153	.7201	.6377	.5662	.5041	.4500	.4028	.3615
.3253	.2935	.2655	.2408	.2190	.1997	.1826	.1675	.1539	.1419
.1311	.1215	.1129	.1052	.0983	.0921	.0866	.0814	.0769	.0727
.0690	.0657	.0626	.0599	.0574	.0552	.0532	.0513	.0497	.0482
.0469	.0458	.0447	.0438	.0430	.0424	.0418	.0414	.0410	.0407
.0406	.0405	.0405	.0406	.0408	.0411	.0415	.0420	.0425	.0432
.0440	.0449	.0458	.0469	.0482	.0495	.0510	.0527	.0545	.0564
.0585	.0609	.0634	.0661	.0691	.0723	.0758	.0796	.0837	.0882
.0930	.0982	.1038	.1099	.1165	.1237	.1314	.1398	.1488	.1586
.1692	.1806	.1930	.2063	.2207	.2362	.2529	.2709	.2902	.3109
.3331	.3568	.3820	.4088	.4371	.4670	.4982	.5307	.5641	.5981
.6320	.6652	.6966	.7246	.7473	.7624	.7677	.7624	.7474	.7247
.6967									

VARIANCE OF S(N)R FROM SIMULATED DATA 1.9103

SMOM(1), SMOM(2) .0000 1.9103

SKEWNESS AND KURTOSIS .1856 2.8841

HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED

24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE

BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ),	NS(N),	HARMONIC COUNT PER BAND	[NS(N):ORIG	SIM	VK	VKA]
4.75571	5.33600	4.23854	211 814 1024	.13569	.01660	.02017
3.77760	4.23854	3.36679	168 647 814	.15966	.01934	.02349
3.00065	3.36679	2.67434	134 514 647	.18387	.02253	.02737
2.38350	2.67434	2.12430	106 409 514	.16827	.02623	.03186
1.89328	2.12430	1.68739	85 325 409	.26570	.03053	.03708
1.50389	1.68739	1.34034	68 258 325	.31210	.03560	.04325
1.19458	1.34034	1.06487	54 205 258	.33003	.04152	.05044
.94889	1.06487	.84570	43 163 205	.05236	.04836	.05875
.75373	.84570	.67176	34 130 163	.05288	.05616	.06821
.59871	.67176	.53360	28 103 130	1.00228	.06539	.07942
.47557	.53360	.42385	22 82 103	.05189	.07627	.09263

.37776	.42385	.33668	17	66	82	.01852	.01652	.00780	.10661
.30007	.33668	.26743	15	52	66	.01189	.01189	.10192	.12374
.23835	.26743	.21243	11	42	52	.01235	.01235	.11799	.14319
.18933	.21243	.16874	10	33	42	.01550	.01550	.13687	.16601
.15039	.16874	.13403	7	27	33	.02138	.02138	.15702	.19029
.11946	.13403	.10647	7	21	27	.03283	.03283	.18182	.21979
.09489	.10647	.08457	5	17	21	.05344	.05344	.21187	.25582
.07537	.08457	.06716	4	14	17	.08037	.08037	.23501	.28297
.05987	.06716	.05336	4	11	14	.12490	.12490	.28717	.32014
.04758	.05336	.04239	3	9	11	.18671	.18671	.30399	.36188
.03778	.04239	.03367	3	7	9	.27240	.27240	.34789	.40890
.03001	.03367	.02674	2	6	7	.35239	.35239	.37895	.43953
.02384	.02674	.02124	2	5	6	.40820	.40820	.39002	.44494

UNBANDIED NSN SPECTRA

.005211	.310629	.310628	.303072	.288604
.010422	.489025	.489025	.390046	.405191
.015833	.479177	.479178	.400658	.439214

ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT

A, B, AMP, ANGLE IN DEGREES - .2191 - .0544 .2258 -166.0499

PHASE ANGLE FOR 1P IN SIMULATED DATA -166.0 DEGREES

OFFSET ANGLE BETWEEN MEAN WIND AND TURBULENCE AT 1P (DELAY) .0 DEGREES

OFFSET, IFFSET, -7.4 11

ONE CYCLE OF MEAN WIND EFFECT - M/S

9.47 9.42 9.47 9.81 9.80 10.00 10.18 10.31 10.39 10.42 10.39 10.31 10.16 10.00 9.80 9.81

NUMBER OF COMPLETE MEAN WIND CYCLES IN SIMULATION 128

VARIANCES FOR FIRST HALF-P AND FOR 0P FROM

SPECTRUM OF SIMULATED DATA, S(N)R

1.1059 .8793 .1462 .0782 .0479 .0336 .0253

SPECTRAL ESTIMATES FROM SIMULATED DATA

FIRST NUMBER IS SERIES MEAN

9.9807	59.8109	45.0039	30.8520	20.4117	13.8403	9.8474	6.9124	5.0728	3.8028
2.9029	2.2527	1.7738	1.4154	1.1435	.9343	.7719	.6441	.5427	.4615
.3959	.3425	.2988	.2624	.2322	.2069	.1855	.1673	.1517	.1364
.1268	.1187	.1079	.1002	.0934	.0874	.0820	.0772	.0730	.0691
.0857	.0825	.0597	.0572	.0549	.0528	.0509	.0492	.0478	.0462
.0450	.0438	.0428	.0419	.0411	.0404	.0398	.0393	.0388	.0385
.0382	.0380	.0379	.0379	.0379	.0381	.0383	.0388	.0390	.0394
.0400	.0407	.0414	.0423	.0433	.0444	.0456	.0470	.0488	.0502
.0521	.0542	.0585	.0590	.0618	.0649	.0683	.0720	.0762	.0808
.0859	.0915	.0978	.1047	.1125	.1211	.1307	.1415	.1538	.1671
.1823	.1994	.2167	.2408	.2653	.2933	.3251	.3613	.4028	.4499
.5040	.5681	.6376	.7200	.8152	.9258	1.0539	1.2033	1.3779	1.5824
1.8227	2.1058	2.4389	2.8303	3.2845	3.7932	4.3113	4.7270	50.0287	4.7272
4.3118	3.7935	3.2847	2.8305	2.4391	2.1058	1.8229	1.5828	1.3780	1.2034
1.0540	.9257	.8153	.7201	.6377	.5682	.5041	.4500	.4028	.3615
.3253	.2935	.2655	.2408	.2190	.1997	.1826	.1675	.1539	.1419
.1311	.1215	.1129	.1052	.0983	.0921	.0865	.0814	.0769	.0727
.0890	.0857	.0828	.0599	.0574	.0552	.0532	.0513	.0497	.0482
.0489	.0458	.0447	.0438	.0430	.0424	.0418	.0414	.0410	.0407
.0408	.0405	.0405	.0408	.0408	.0411	.0415	.0420	.0425	.0432
.0440	.0449	.0458	.0489	.0482	.0495	.0510	.0527	.0545	.0584
.0585	.0609	.0634	.0661	.0691	.0723	.0758	.0798	.0837	.0882
.0930	.0982	.1038	.1099	.1165	.1237	.1314	.1398	.1488	.1588
.1692	.1806	.1930	.2063	.2207	.2362	.2529	.2709	.2902	.3109

.3331	.3568	.3820	.4088	.4371	.4670	.4982	.5307	.5641	.5981
.6320	.6652	.6968	.7246	.7473	.7624	.2449	.7624	.7474	.7247
.6967									

VARIANCE OF S(N)R FROM SIMULATED DATA 2.1426

SMOW(1), SMOW(2) 9.9607 2.1426

SKEWNESS AND KURTOSIS .1305 2.8488

HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED

24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE

BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ),	NS(N),	HARMONIC COUNT PER BAND	[NS(N):ORIG	SIM	VK	VKA]
4.75571 5.33600 4.23854 211 814 1024	.13569	.13569	.01660	.02017		
3.77760 4.23854 3.36679 188 847 814	.15986	.15986	.01934	.02349		
3.00065 3.36679 2.67434 134 514 647	.18387	.18388	.02253	.02737		
2.38350 2.67434 2.12430 106 489 514	.16827	.16834	.02623	.03186		
1.89320 2.12430 1.60739 85 325 409	.26570	.26502	.03053	.03708		
1.50389 1.60739 1.34034 68 258 325	.31210	.31210	.03560	.04325		
1.19450 1.34034 1.06467 54 205 258	.33003	.31847	.04152	.05044		
.94889 1.06467 .84570 43 163 205	.05236	.05236	.04836	.05875		
.75373 .84570 .67176 34 130 163	.05288	.05288	.05616	.06821		
.59871 .67176 .53360 28 103 130	1.00228	1.96745	.06539	.07942		
.47557 .53360 .42385 22 82 103	.05189	.05189	.07627	.09263		
.37776 .42385 .33668 17 66 82	.01652	.01652	.08780	.10661		
.30007 .33668 .26743 15 52 66	.01189	.01189	.10192	.12374		
.23835 .26743 .21243 11 42 52	.01235	.01235	.11799	.14319		
.18933 .21243 .16874 10 33 42	.01550	.01550	.13687	.16601		
.15039 .16874 .13403 7 27 33	.02136	.02136	.15702	.19029		
.11946 .13403 .10647 7 21 27	.03283	.03283	.18162	.21979		
.09489 .10647 .08457 5 17 21	.05344	.05344	.21187	.25582		
.07537 .08457 .06718 4 14 17	.08037	.08037	.23501	.28297		
.05987 .06718 .05336 4 11 14	.12490	.12490	.26717	.32014		
.04756 .05336 .04239 3 9 11	.18671	.18671	.30399	.36168		
.03776 .04239 .03367 3 7 9	.27240	.27240	.34769	.40890		
.03001 .03367 .02674 2 6 7	.35239	.35239	.37895	.43953		
.02384 .02674 .02124 2 5 6	.40820	.40820	.39002	.44494		

UNBANDED NSN SPECTRA

.005211	.310829	.310629	.303072	.286604
.010422	.469025	.469025	.390046	.405191
.015633	.479177	.479178	.400656	.439214

APPENDIX D

SAMPLE OUTPUT FROM THE FILE SERIES.DAT FOR THE
HAWT CASE AT HALF-BLADE RADIUS

APPENDIX D

SAMPLE OUTPUT FROM THE FILE SERIES.DAT FOR THE HAWT CASE AT HALF-BLADE RADIUS

D.1 SAMPLE FILE FOR TURBULENT PART OF THE WIND

2048	2.076073	9.400751E-01	5.664328E-01	2.338139
1.843446	1.021647	1.358754	2.156074	
3.316686	1.613472	1.217244	1.930235	
1.614217	9.914294E-01	6.968585E-01	1.686051	
1.935520	2.186547	1.074212	2.185608	
2.647616	2.970832	1.559561	2.269849	
1.275372	1.484519	5.747703E-01	1.501596	
1.881323	1.532165	9.291232E-01	1.187948	
2.091939	1.908166	9.984764E-01	1.095258	
1.870421	9.922648E-01	6.226134E-01	7.182071E-01	
1.458670	5.219072E-01	8.686469E-01	1.973248	
2.713935	1.305969	-1.167601E-01	6.344846E-01	
1.647073	1.265098	8.355237E-01	2.671025E-02	
-1.094317	-7.755048E-01	8.751794E-01	1.148944	
1.099581	3.767361E-01	7.943738E-01	8.309373E-01	
1.112830	9.644930E-01	-4.941007E-02	1.099572	
6.748724E-01	-2.477923E-01	5.105027E-01	1.714794E-01	
-8.316345E-01	-1.086399	-1.216976	-3.746083E-01	
1.287471E-01	4.849330E-02	1.339363	1.072747	
-2.565026E-02	3.002124E-01	5.216386E-01	-8.856194E-02	
-7.985926E-01	-9.716650E-01	7.518607E-02	-2.097629E-01	
-1.613284	-1.534747	-7.154712E-01	-6.738887E-01	
-8.762276E-02	1.008137	1.480822	2.807857E-01	
6.483487E-01	1.107034	-2.648050E-02	-4.597069E-01	
-8.962698E-01	1.439541E-01	4.306168E-01	-1.174921	
-1.148373	-2.817943	-2.212637	-9.933257E-01	
7.421699E-01	5.665348E-01	-4.086412E-01	-6.890477E-01	
3.886703E-01	9.821851E-01	7.135606E-01	-5.989395E-01	
-1.892408	-1.171757	-6.695012E-01	-7.477893E-01	
-8.728871E-01	-1.622636	-1.818481	-9.895428E-01	
-8.259388E-01	-4.204648E-01	3.056279E-01	7.699955E-01	
5.101993E-01	4.339325E-02	-2.247749E-01	-2.478203E-01	
-1.409999	-7.141615E-01	1.208970E-01	-8.139611E-01	
-3.846259E-01	-5.958565E-01	-1.345321	1.094725E-01	
-7.321773E-01	1.250880E-01	4.024305E-01	1.059080	
2.952845E-01	-8.368164E-01	-8.456659E-02	-1.629203	
-1.786981	1.888407E-01	1.147803	-4.316662E-01	
7.406739E-01	7.312166E-01	-2.507349E-01	2.018883E-01	
4.718580E-01	-4.228624E-01	-2.542650E-01	-5.940416E-01	
-3.527985E-01	-7.432396E-01	-9.528984E-01	-6.578938E-01	
-8.893788E-01	-7.120957E-01	-2.836452E-01	3.919008E-01	
1.848891E-01	3.794590E-01	1.079795	6.194966E-01	
6.413932E-01	2.434153E-01	-1.104215	-1.621078	
-1.426739	-2.013039	-1.139686	1.952785E-01	

2.389396E-01	2.586895E-01	-4.403980E-01	-5.120499E-01
4.654599E-01	3.748999E-01	4.866753E-01	4.629282E-01
4.228266E-01	-1.243848	-1.392797	-5.402253E-01
-8.789260E-01	-8.618394E-01	-4.412740E-01	6.633582E-01
5.132513E-01	-6.676229E-02	1.519745E-01	-5.333039E-01
2.893252E-01	8.658149E-01	1.251635	3.742760E-01
-8.879077E-01	-1.590529	-1.857567	-1.977337
-1.324166	-6.970474E-01	-7.668741E-01	7.605446E-01
-9.390742E-02	1.914034E-01	1.058972	-5.772703E-01
-7.063335E-01	-6.770900E-01	9.640802E-01	7.786233E-01
3.891642E-01	-1.422647	-1.701642	-2.269276
-7.367760E-01	6.756864E-01	-1.784716E-01	1.382987
1.089556	1.448520	1.186957	-1.266867E-01
-3.865625E-01	-7.488615E-01	1.817799E-01	2.680401E-01
-8.947815E-01	-1.297430	-1.233360	-2.578604
-2.281215	-1.799450	-1.081927E-01	1.173131
1.222859	1.012385	8.129695E-01	-3.356437E-01
2.112708E-01	1.752460E-01	1.320962E-01	4.122001E-01
-3.660117E-01	-3.712884E-01	-1.412306	-1.506803
-1.093969	-1.733226	1.461598E-01	7.272745E-01
9.996289E-01	1.067426	8.014847E-01	-9.882981E-02
-6.619879E-01	-1.377589E-01	-2.389369E-01	-2.438908E-01
-7.785997E-01	-1.547865	-1.826867	-6.538156E-01
-3.961572E-02	1.286612E-01	-4.687365E-01	6.118602E-01
-3.618800E-01	4.329997E-01	-2.405456E-01	-1.148513
-2.667359E-01	8.061666E-01	-7.707934E-01	-3.945635E-01
4.522759E-02	-1.943646	-1.046264	-3.632769E-01
-3.092958E-02	1.291391E-01	4.928303E-01	2.842263E-01
-2.057778E-01	-1.037681	-1.187494	-6.598514E-01
3.768280E-02	6.564618E-01	4.523647E-01	-1.036177
8.304861E-01	7.427335E-02	-1.088347	-4.741601E-01
-2.237248E-01	-3.141608E-01	9.848756E-02	-5.505564E-01
-5.074259E-01	-1.622937	-2.445074	-9.582552E-02
9.252548E-01	7.660846E-01	4.336451E-01	1.002876E-01
8.714794E-01	6.146393E-01	7.813359E-01	-3.054557E-01
-8.664709E-01	-1.063849	-1.151340	-8.370621E-01
-7.595584E-01	-2.132871	-1.071164	-5.379018E-01
5.211271E-01	5.631825E-01	4.975958E-01	7.969086E-01
4.385185E-01	-2.805782E-01	-8.766341E-02	-1.470283E-01
1.790620E-01	-7.848344E-01	-9.576132E-01	-1.194698
-9.422884E-01	-1.527152	-1.627165	-1.251946
-6.517717E-01	-1.004805E-01	-4.251462E-01	-6.087676E-01
-1.270611	-1.542978	-8.467219E-01	-1.741547E-01
5.643666E-01	-1.699240E-01	-5.214103E-01	-9.946434E-01
-9.392869E-01	-1.718435E-01	-2.326468	-7.609184E-01
-1.581491	-6.798834E-02	-6.562498E-01	-1.165518
-1.207915	-1.090602	1.609885E-01	4.218521E-01
-6.220839E-01	-8.532871E-01	-9.353518E-01	-1.617091
-1.063427	-2.107415E-01	-9.364847E-01	-1.209996
-1.834853	-1.494505	-3.634915E-01	-1.007462
-1.806963	-7.807907E-01	1.264636	1.787322
8.166504E-02	-1.105034	-8.656137E-02	-9.078007E-01

D.2 FLUCTUATIONS CAUSED BY ROTATION THROUGH THE TOTAL WIND

2048	11.546950	10.358170	10.037310	11.950240
11.645550	11.021650	11.534340	12.466440	
13.711030	12.036260	11.611580	12.240600	
11.789800	10.991430	10.498960	11.298150	
11.406400	11.604640	10.545090	11.797710	
12.449720	12.970830	11.735150	12.580220	
11.669710	11.907310	10.969110	11.811960	
12.056910	11.532170	10.731230	10.800050	
11.562820	11.326260	10.469360	10.707360	
11.672520	10.992260	10.798200	11.028570	
11.853010	10.944690	11.262990	12.283620	
12.889520	11.305970	9.685343	10.246590	
11.117950	10.683190	10.306410	9.638812	
8.707787	9.224495	11.050770	11.459310	
11.493920	10.799520	11.188710	11.141300	
11.288420	10.964490	9.752693	10.711670	
10.145750	9.170300	9.981384	9.783581	
8.970469	8.913601	8.958610	9.935760	
10.523090	10.471280	11.733700	11.383110	
10.149940	10.300210	10.323740	9.523540	
8.672288	8.446427	9.546067	9.402339	
8.188819	8.465253	9.460114	9.636478	
10.306720	11.430920	11.875160	10.591150	
10.823930	11.107030	9.775622	9.152394	
8.574611	9.562047	9.901498	8.437181	
8.653730	7.182057	7.962949	9.317041	
11.136510	10.989320	9.985700	9.621320	
10.564260	10.982190	10.515660	9.013162	
7.578473	8.246336	8.801380	8.864312	
8.929216	8.377364	8.357105	9.320825	
9.568401	10.002320	10.699970	11.080360	
10.685790	10.043390	9.577328	9.364282	
8.060882	8.703931	9.591779	8.798141	
9.417477	9.404143	8.830265	10.419840	
9.662163	10.547880	10.796770	11.369450	
10.470870	9.163183	9.717537	7.982899	
7.683899	9.606934	10.618680	9.180435	
10.542780	10.731220	9.924850	10.512260	
10.866200	9.999926	10.140080	9.716326	
9.822787	9.256761	8.849205	8.954207	
8.581502	8.705997	9.187236	10.004000	
9.986992	10.379460	11.255380	10.929860	
11.035730	10.666200	9.290126	8.689289	
8.748847	7.986961	8.662417	9.807380	
9.709820	9.676783	9.030483	9.100052	
10.267560	10.374900	10.662260	10.773300	
10.817170	9.178940	9.001543	9.770143	
9.296659	9.138161	9.360829	10.275460	
9.984132	9.351331	9.622856	9.078797	
10.091430	10.865820	11.427220	10.684640	

9.506433	8.832258	8.536774	8.333031
8.851419	9.302953	9.035229	10.372650
9.376973	9.609496	10.529850	9.034831
9.095770	9.322910	11.139670	11.088990
10.783500	9.000141	8.692698	8.041092
9.438809	10.675690	9.623631	10.995090
10.560440	10.866610	10.657840	9.485415
9.415541	9.251139	10.357370	10.578410
9.499559	9.125358	9.160980	7.731764
7.894371	8.200550	9.693911	10.785230
10.693740	10.430480	10.283850	9.276458
10.013370	10.175250	10.307680	10.722570
10.028330	10.051500	8.982035	8.803564
9.081616	8.266774	9.948263	10.339380
10.470510	10.485520	10.272370	9.513271
9.140115	9.862241	9.936649	10.066480
9.615741	8.874923	8.567473	9.656552
10.135970	10.128660	9.333366	10.223960
9.109000	9.851092	9.230336	8.463589
9.535367	10.806170	9.404793	9.915804
10.439570	8.479141	9.348077	9.947091
10.144660	10.129140	10.294930	9.896328
9.265102	8.380412	8.283387	8.952250
9.839786	10.656460	10.627950	9.274191
11.224830	10.497060	9.305994	9.836207
9.951861	9.685840	9.900591	9.061545
8.963454	7.795156	7.025807	9.516276
10.727360	10.766080	10.609230	10.410660
11.265820	11.037430	11.175680	10.004910
9.309114	8.936152	8.650763	8.775040
8.711322	7.285222	8.399717	9.074200
10.323230	10.563180	10.673180	11.107280
10.832860	10.142210	10.306680	10.163340
10.354650	9.215166	8.844490	8.417403
8.528592	7.890941	7.843717	8.360155
9.150331	9.899520	9.750440	9.701600
9.123730	8.879809	9.547619	10.136210
10.739950	9.830076	9.280693	8.617458
8.531593	9.246249	7.144413	8.851183
8.220612	9.932012	9.519336	9.144850
9.186425	9.332186	10.555330	10.732220
9.553502	9.146713	8.866752	7.995010
8.407454	9.207352	8.534397	8.402105
7.967250	8.505495	9.812095	9.302906
8.587378	9.641997	11.658980	12.097690
10.257250	8.894966	9.715542	8.704301
8.247301	9.298132	9.142229	7.932896
7.991766	7.637530	9.185664	9.885296
9.464486	10.319710	11.646670	11.999120
9.733490	9.170468	8.931449	8.480384
8.722915	8.219355	7.364740	8.182442
8.382736	9.204282	9.297139	9.805149

APPENDIX E

SAMPLE OUTPUT FROM ALL FILES FOR THE
HAWT CASE AT FULL-BLADE RADIUS

E.1 SUMMARY.BRF FOR FULL-TIP RADIUS

HAWT SIMULATION
 SERIAL NUMBER HT100
 RADIUS OF ROTATION 19.0 M
 RATE OF ROTATION .6670 HZ
 HUB HEIGHT 30.5 M
 SURFACE ROUGHNESS LENGTH .0500 M
 MEAN WIND SPEED 10.00 M/S
 TURBULENCE RMS VALUES
 U-COMPONENT 1.497 M/S
 V-COMPONENT 1.497 M/S
 TURBULENCE VARIANCES
 U-COMPONENT 2.241 (M/S)**2
 V-COMPONENT 2.241 (M/S)**2
 FRICTION VELOCITY .624 M/S
 TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 120.1 M
 LATERAL 51.2 M
 NUMBER DATA TO BE SIMULATED 2048
 DISCRETIZATION INTERVAL .0937 SEC
 ALIAS FACTOR 4
 ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
 ANGLE WAS READ IN - DT WAS CALCULATED
 ALFA, BETA .3708 .0188
 LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
 NUMBER OF HARMONICS IN SPECTRA 1024
 THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
 SPECTRUM AND REDUCED VERSION.
 FUNDAMENTAL FREQUENCY IS .005211 HZ

 MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
 VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.1012 (M/S)**2
 VARIANCES FOR FIRST HALF-P AND FOR 8P FROM 80-MEMBER SPECTRUM
 S(N)C, - (M/S)**2
 .7683 .7603 .2383 .1200 .0754 .0530 .0400
 RMS
 .8765 .8720 .4881 .3464 .2746 .2303 .1999
 SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
 .5600 .0832 .0237 .0119 .0074 .0051 .0037
 VARIANCES FOR FIRST HALF-P AND FOR 8P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .7303 .5693 .2244 .1190 .0753 .0530 .0400
 VARIANCE OF S(N)R FROM SIMULATED DATA 1.8559
 SKEWNESS AND KURTOSIS -.0028 2.8664
 ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT
 VARIANCES FOR FIRST HALF-P AND FOR 8P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .7303 1.5054 .2144 .1169 .0760 .0531 .0400
 VARIANCE OF S(N)R FROM SIMULATED DATA 2.7808
 SKEWNESS AND KURTOSIS -.0535 2.7323

E.2 SUMMARY.DAT FOR FULL-TIP RADIUS

HAWT SIMULATION
SERIAL NUMBER HT100
RADIUS OF ROTATION 19.0 M
RATE OF ROTATION .6670 HZ
HUB HEIGHT 30.5 M
SURFACE ROUGHNESS LENGTH .0500 M
MEAN WIND SPEED 10.00 M/S
TURBULENCE RMS VALUES
 U-COMPONENT 1.497 M/S
 V-COMPONENT 1.497 M/S
TURBULENCE VARIANCES
 U-COMPONENT 2.241 (M/S)**2
 V-COMPONENT 2.241 (M/S)**2
FRICTION VELOCITY .624 M/S
TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 128.1 M
 LATERAL 51.2 M
NUMBER DATA TO BE SIMULATED 2048
DISCRETIZATION INTERVAL .0937 SEC
ALIAS FACTOR 4
ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
ANGLE WAS READ IN - DT WAS CALCULATED
ALFA, BETA .3708 .0186
LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
NUMBER OF HARMONICS IN SPECTRA 1024
THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
SPECTRUM AND REDUCED VERSION.
FUNDAMENTAL FREQUENCY IS .005211 HZ

MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
DIFFERENT FORMS OF VARIABLES:
 - ORIGINAL
 -A - INCLUDING EXTENSIONS ASSOCIATED WITH ALIAS REMOVAL
 -ND - DIMENSIONLESS VARIABLE
 -AND - BOTH OF THE ABOVE
DISCRETIZATION INTERVAL - DT
 .094 SEC
 -A .023 SEC
 -ND .196
 -AND .049
NUMBER OF SIMULATED DATA - MMT
 2048
 -A 8192
FUNDAMENTAL FREQUENCY - EN1
 .00521 HZ
 -ND .00249
NYQUIST FREQUENCY - EN2
 5.33000 HZ
 -A 21.34400 HZ

ND 2.54648
 AND 10.18592
 NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE
 18
 A 64
 HANNING WINDOW USED - LAST R BEFORE USE .0010
 AUTOCORRELATION FUNCTION 3413 STEPS 79.95 SECONDS
 AFTER FIRST VALUE SKIP INTERVAL IS 4

.0610	.6137	.4642	.3627	.2931	.2464	.2171	.2019	.1990	.2079	.2297	.2669	.3238	.4069	.5259
.6894	.7601	.5979	.4584	.3598	.2914	.2453	.2184	.2013	.1983	.2071	.2284	.2647	.3195	.3976
.5020	.6150	.6452	.5524	.4401	.3508	.2863	.2421	.2141	.1994	.1964	.2047	.2251	.2593	.3098
.3787	.4621	.5366	.5518	.4939	.4099	.3345	.2766	.2357	.2093	.1953	.1923	.1999	.2187	.2498
.2944	.3520	.4157	.4657	.4742	.4353	.3732	.3121	.2622	.2256	.2016	.1886	.1857	.1924	.2092
.2364	.2744	.3210	.3690	.4037	.4086	.3810	.3348	.2861	.2443	.2126	.1912	.1794	.1766	.1825
.1970	.2203	.2518	.2889	.3251	.3497	.3526	.3323	.2973	.2587	.2243	.1973	.1787	.1683	.1657
.1706	.1829	.2024	.2281	.2574	.2849	.3028	.3045	.2891	.2623	.2317	.2035	.1809	.1650	.1559
.1535	.1575	.1678	.1839	.2047	.2278	.2488	.2620	.2630	.2511	.2302	.2059	.1830	.1641	.1506
.1428	.1406	.1439	.1523	.1655	.1823	.2006	.2167	.2266	.2270	.2177	.2013	.1819	.1632	.1476
.1362	.1296	.1278	.1302	.1371	.1479	.1614	.1758	.1883	.1957	.1959	.1885	.1755	.1599	.1447
.1318	.1223	.1166	.1148	.1169	.1226	.1313	.1421	.1535	.1632	.1689	.1689	.1629	.1528	.1401
.1276	.1170	.1090	.1042	.1027	.1043	.1089	.1159	.1246	.1337	.1413	.1456	.1454	.1406	.1323
.1222	.1121	.1033	.0966	.0926	.0912	.0925	.0962	.1019	.1089	.1161	.1220	.1253	.1251	.1212
.1145	.1063	.0980	.0907	.0852	.0818	.0806	.0816	.0846	.0892	.0948	.1005	.1052	.1077	.1075
.1043	.0988	.0922	.0854	.0794	.0748	.0719	.0709	.0717	.0741	.0778	.0823	.0868	.0905	.0925
.0922	.0896	.0851	.0797	.0741	.0692	.0654	.0630	.0621	.0627	.0646	.0676	.0712	.0748	.0777
.0792	.0789	.0768	.0732	.0687	.0642	.0601	.0569	.0549	.0541	.0546	.0561	.0585	.0614	.0643
.0666	.0678	.0675	.0657	.0628	.0591	.0554	.0520	.0494	.0477	.0470	.0474	.0486	.0505	.0528
.0551	.0570	.0579	.0576	.0561	.0537	.0507	.0477	.0449	.0427	.0413	.0407	.0410	.0419	.0435
.0453	.0472	.0486	.0493	.0491	.0478	.0459	.0434	.0409	.0386	.0368	.0356	.0351	.0353	.0361
.0373	.0388	.0403	.0414	.0419	.0417	.0407	.0391	.0371	.0350	.0331	.0316	.0306	.0302	.0303
.0309	.0319	.0331	.0343	.0352	.0356	.0354	.0345	.0332	.0316	.0299	.0283	.0271	.0262	.0259
.0260	.0264	.0272	.0282	.0291	.0298	.0301	.0299	.0292	.0281	.0268	.0254	.0241	.0231	.0224
.0221	.0221	.0225	.0231	.0239	.0246	.0252	.0254	.0253	.0247	.0238	.0227	.0215	.0205	.0196
.0191	.0188	.0188	.0191	.0196	.0202	.0208	.0212	.0214	.0213	.0208	.0200	.0191	.0182	.0173
.0166	.0162	.0159	.0160	.0162	.0166	.0171	.0175	.0178	.0180	.0178	.0175	.0168	.0161	.0153
.0146	.0141	.0137	.0135	.0135	.0137	.0140	.0143	.0147	.0150	.0151	.0149	.0146	.0141	.0135
.0129	.0123	.0118	.0115	.0113	.0113	.0115	.0117	.0120	.0123	.0125	.0126	.0125	.0122	.0118
.0113	.0108	.0103	.0099	.0097	.0095	.0095	.0096	.0098	.0100	.0102	.0104	.0105	.0104	.0101
.0098	.0094	.0090	.0086	.0083	.0081	.0079	.0079	.0080	.0082	.0083	.0085	.0086	.0087	.0086
.0084	.0081	.0078	.0075	.0072	.0069	.0067	.0066	.0066	.0067	.0068	.0069	.0070	.0071	.0072
.0071	.0069	.0067	.0065	.0062	.0059	.0057	.0056	.0055	.0055	.0055	.0056	.0057	.0058	.0059
.0059	.0058	.0057	.0055	.0053	.0051	.0049	.0047	.0046	.0045	.0045	.0045	.0046	.0047	.0048
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.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
VARIANCE FROM INTEGRATION OF ROTATIONAL S(M)														
COMPUTED BY FFT OF ACF 1.055939 (M/S)**2														
VON KARMAN S(N) SPECTRUM														
74.909900	55.000400	38.878940	28.095660	21.037690	16.297410	12.998020	10.820640	8.854130	7.506222					
6.453985	5.616299	4.938014	4.380636	3.916657	3.526003	3.193743	2.908588	2.661872	2.446850					
2.258207	2.091707	1.943941	1.812139	1.694030	1.587736	1.491696	1.404601	1.325348	1.252998					
1.186754	1.125929	1.069934	1.018258	.970456	.926140	.884970	.846849	.810912	.777525					
.746282	.716998	.689508	.663665	.639336	.616402	.594755	.574298	.554943	.536611					
.519227	.502727	.487050	.472139	.457946	.444422	.431526	.419218	.407482	.396225					
.385475	.375184	.365325	.355874	.346808	.338106	.329748	.321715	.313991	.306560					
.299405	.292514	.285874	.279471	.273294	.267333	.261577	.256017	.250644	.245448					
.240423	.235561	.230853	.226295	.221879	.217599	.213449	.209425	.205521	.201731					
.198053	.194480	.191010	.187637	.184359	.181171	.178071	.175055	.172119	.169262					
.166480	.163770	.161130	.158557	.156050	.153605	.151221	.148896	.146627	.144413					
.142252	.140143	.138083	.136071	.134105	.132185	.130308	.128474	.126680	.124926					
.123211	.121533	.119891	.118285	.116712	.115173	.113666	.112190	.110745	.109330					
.107943	.106584	.105252	.103946	.102667	.101412	.100182	.098975	.097791	.096630					
.095491	.094373	.093276	.092199	.091142	.090105	.089086	.088085	.087102	.086137					
.085188	.084256	.083341	.082441	.081557	.080687	.079833	.078993	.078167	.077354					
.076555	.075770	.074997	.074236	.073488	.072752	.072027	.071314	.070613	.069922					
.069242	.068572	.067913	.067264	.066625	.065995	.065375	.064764	.064162	.063569					
.062985	.062409	.061842	.061283	.060732	.060189	.059654	.059126	.058605	.058092					
.057586	.057087	.056595	.056110	.055631	.055159	.054693	.054234	.053780	.053333					
.052892	.052456	.052028	.051602	.051183	.050770	.050362	.049959	.049561	.049168					
.048781	.048398	.048020	.047646	.047278	.046914	.046554	.046198	.045847	.045501					
.045156	.044820	.044485	.044155	.043828	.043505	.043187	.042871	.042560	.042252					
.041948	.041647	.041349	.041055	.040764	.040477	.040193	.039912	.039634	.039359					
.039067	.038816	.038553	.038290	.038030	.037772	.037518	.037268	.037017	.036770					
.036527	.036285	.036047	.035810	.035577	.035345	.035117	.034890	.034666	.034444					
.034224	.034007	.033792	.033579	.033368	.033159	.032952	.032748	.032545	.032344					
.032146	.031949	.031754	.031561	.031370	.031181	.030994	.030808	.030624	.030442					
.030262	.030083	.029906	.029731	.029557	.029385	.029215	.029046	.028879	.028713					
.028549	.028386	.028225	.028065	.027906	.027750	.027594	.027440	.027287	.027136					
.026986	.026837	.026689	.026543	.026398	.026255	.026112	.025971	.025831	.025693					
.025555	.025419	.025283	.025149	.025017	.024885	.024754	.024624	.024496	.024368					
.024242	.024117	.023992	.023869	.023747	.023626	.023505	.023386	.023268	.023150					
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.020888	.020790	.020691	.020594	.020498	.020402	.020307	.020212	.020118	.020025					
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.015427	.015366	.015306	.015246	.015186	.015126	.015067	.015009	.014951	.014893
.014835	.014778	.014721	.014665	.014609	.014553	.014497	.014442	.014387	.014333
.014279	.014225	.014171	.014118	.014065	.014013	.013961	.013909	.013857	.013806
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.012795	.012750	.012705	.012661	.012616	.012572	.012528	.012485	.012441	.012398
.012355	.012312	.012270	.012228	.012186	.012144	.012102	.012061	.012020	.011979
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.011544	.011506	.011468	.011430	.011392	.011355	.011317	.011280	.011243	.011207
.011170	.011134	.011098	.011062	.011026	.010990	.010955	.010920	.010885	.010850
.010815	.010781	.010748	.010712	.010678	.010644	.010611	.010577	.010544	.010511
.010478	.010445	.010412	.010380	.010347	.010315	.010283	.010252	.010220	.010188
.010157	.010126	.010095	.010064	.010033	.010002	.009972	.009942	.009911	.009881
.009852	.009822	.009792	.009763	.009734	.009704	.009675	.009646	.009618	.009589
.009561	.009532	.009504	.009476	.009448	.009420	.009393	.009365	.009338	.009310
.009283	.009256	.009229	.009203	.009176	.009149	.009123	.009097	.009070	.009044
.009018	.008993	.008967	.008941	.008916	.008891	.008865	.008840	.008815	.008790
.008766	.008741	.008716	.008692	.008668	.008643	.008619	.008595	.008571	.008548
.008524	.008500	.008477	.008453	.008430	.008407	.008384	.008361	.008338	.008315
.008293	.008270	.008248	.008225	.008203	.008181	.008159	.008137	.008115	.008093
.008071	.008050	.008028	.008007	.007985	.007964	.007943	.007922	.007901	.007880
.007859	.007838	.007818	.007797	.007777	.007756	.007736	.007716	.007696	.007676
.007656	.007636	.007616	.007597	.007577	.007557	.007538	.007519	.007499	.007480
.007461	.007442	.007423	.007404	.007385	.007366	.007348	.007329	.007311	.007292
.007274	.007255	.007237	.007219	.007201	.007183	.007165	.007147	.007129	.007112
.007094	.007076	.007059	.007041	.007024	.007007	.006990	.006972	.006955	.006938
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.006755	.006739	.006723	.006706	.006690	.006674	.006658	.006643	.006627	.006611
.006595	.006580	.006564	.006548	.006533	.006518	.006502	.006487	.006472	.006457
.006441	.006426	.006411	.006396	.006381	.006367	.006352	.006337	.006322	.006308
.006293	.006279	.006264	.006250	.006235	.006221	.006207	.006193	.006178	.006164
.006150	.006136	.006122	.006109	.006095	.006081	.006067	.006053	.006040	.006026
.006013	.005999	.005986	.005972	.005959	.005946	.005932	.005919	.005906	.005893
.005880	.005867	.005854	.005841	.005828	.005815	.005802	.005790	.005777	.005764
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.005508	.005496	.005485	.005473	.005462	.005450	.005438	.005427	.005415	.005404
.005393	.005381	.005370	.005359	.005347	.005336	.005325	.005314	.005303	.005292
.005281	.005270	.005259	.005248	.005237	.005226	.005216	.005205	.005194	.005183
.005173	.005162	.005152	.005141	.005131	.005120	.005110	.005099	.005089	.005079
.005068	.005058	.005048	.005038	.005027	.005017	.005007	.004997	.004987	.004977
.004967	.004957	.004947	.004937	.004927	.004918	.004908	.004898	.004888	.004879
.004869	.004859	.004850	.004840	.004831	.004821	.004812	.004802	.004793	.004783
.004774	.004765	.004755	.004746	.004737	.004728	.004718	.004709	.004700	.004691
.004682	.004673	.004664	.004655	.004646	.004637	.004628	.004619	.004610	.004601
.004593	.004584	.004575	.004566	.004558	.004549	.004540	.004532	.004523	.004515
.004506	.004498	.004489	.004481	.004472	.004464	.004455	.004447	.004439	.004430
.004422	.004414	.004406	.004397	.004389	.004381	.004373	.004365	.004357	.004349
.004341	.004333	.004325	.004317	.004309	.004301	.004293	.004285	.004277	.004269
.004262	.004254	.004246	.004238	.004231	.004223	.004215	.004208	.004200	.004192
.004185	.004177	.004170	.004162	.004155	.004147	.004140	.004132	.004125	.004117
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.003967	.003960	.003953	.003946	.003939	.003932	.003926	.003919	.003912	.003905
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.003704	.003698	.003691	.003685	.003679	.003673	.003667	.003661	.003654	.003648
.003642	.003636	.003630	.003624	.003618	.003612	.003606	.003600	.003594	.003588
.003582	.003577	.003571	.003565	.003559	.003553	.003547	.003541	.003536	.003530
.003524	.003518	.003513	.003507						
S(N) ESTIMATES FROM FFT OF ACF									
51.330400	45.863720	33.028760	20.965880	12.797390	7.921397	5.057817	3.348401	2.295381	1.628645
1.192480	.899420	.696931	.563058	.448625	.370590	.311319	.265153	.228606	.199222
.175135	.155269	.138555	.124463	.112427	.102060	.093113	.085282	.078460	.072435
.067121	.062413	.058208	.054476	.051115	.048113	.045407	.042985	.040769	.038771
.036970	.035331	.033849	.032502	.031268	.030157	.029141	.028223	.027386	.026627
.025944	.025322	.024768	.024268	.023824	.023433	.023088	.022793	.022539	.022330
.022162	.022033	.021944	.021894	.021866	.021913	.021979	.022085	.022231	.022420
.022649	.022924	.023243	.023610	.024030	.024501	.025032	.025622	.026279	.027008
.027812	.028702	.029683	.030765	.031957	.033274	.034728	.036332	.038107	.040072
.042254	.044678	.047380	.050399	.053779	.057579	.061861	.066708	.072213	.078491
.085885	.093968	.103549	.114695	.127736	.143080	.161247	.182897	.208864	.240223
.278348	.325030	.382591	.454060	.543433	.655954	.798602	.980622	1.214380	1.516272
1.908218	2.419029	3.085502	3.951738	5.059844	6.417074	7.904862	9.158943	9.863895	9.159512
7.905490	6.417857	5.080452	3.952163	3.085783	2.419202	1.908315	1.516315	1.214367	.980605
.798570	.655914	.543388	.454015	.382546	.324989	.278310	.240189	.208836	.182874
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.061900	.057823	.053829	.050454	.047442	.044746	.042327	.040152	.038193	.036425
.034827	.033381	.032072	.030888	.029814	.028842	.027981	.027166	.026448	.025802
.025222	.024705	.024246	.023842	.023489	.023186	.022930	.022719	.022551	.022427
.022345	.022304	.022303	.022344	.022427	.022552	.022719	.022931	.023188	.023493
.023847	.024253	.024715	.025235	.025818	.026468	.027191	.027992	.028879	.029859
.030940	.032133	.033451	.034904	.036509	.038282	.040243	.042416	.044825	.047501
.050478	.053798	.057503	.061651	.066303	.071535	.077431	.084092	.091635	.100201
.109951	.121078	.133808	.148408	.165193	.184532	.206861	.232893	.262626	.297362
.337712	.384614	.439139	.502492	.576008	.661122	.759312	.871989	1.000315	1.144879
1.305182	1.478809	1.660112	1.838320	1.995439	2.106529	2.147118	2.106613	1.995581	1.838488
1.660282	1.478965	1.305319	1.144994	1.000410	.872067	.759373	.661171	.576048	.502524
.439166	.384638	.337734	.297384	.262650	.232718	.206889	.184563	.165229	.148449
.133853	.121128	.110006	.100282	.091702	.084185	.077511	.071622	.066397	.061751
.057810	.053912	.050801	.047832	.044985	.042585	.040402	.038450	.036687	.035093
.033851	.032347	.031186	.030097	.029132	.028260	.027474	.026768	.026136	.025572
.025072	.024632	.024248	.023918	.023640	.023411	.023229	.023094	.023004	.022958
.022956	.022999	.023086	.023218	.023395	.023620	.023892	.024215	.024590	.025019
.025507	.026055	.026669	.027352	.028109	.028947	.029872	.030890	.032010	.033241
.034594	.036079	.037710	.039502	.041471	.043635	.046014	.048632	.051515	.054693
.058198	.062067	.066342	.071070	.076303	.082099	.088524	.095651	.103568	.112342
.122095	.132929	.144961	.158320	.173142	.189571	.207759	.227855	.250009	.274359
.301022	.330083	.361578	.395489	.431617	.469753	.509432	.549991	.590503	.629731
.666106	.697746	.722558	.738501	.744017	.738516	.722589	.697788	.666156	.629786
.590560	.550049	.509489	.469809	.431672	.395523	.361631	.330136	.301074	.274411
.250062	.227910	.207816	.189831	.173205	.158386	.145032	.133004	.122175	.112426
.103650	.095746	.088825	.082207	.076417	.071191	.066471	.062203	.058341	.054845
.051876	.048801	.046192	.043823	.041669	.039711	.037931	.036311	.034838	.033496
.032279	.031173	.030169	.029260	.028438	.027697	.027031	.026436	.025906	.025439
.025030	.024678	.024376	.024129	.023931	.023780	.023676	.023617	.023605	.023638
.023716	.023839	.024009	.024225	.024491	.024806	.025172	.025592	.026068	.026603
.027200	.027862	.028594	.029400	.030284	.031253	.032313	.033471	.034732	.036107
.037604	.039234	.041005	.042932	.045026	.047302	.049775	.052462	.055381	.058551

.061994	.065733	.069790	.074192	.078966	.084139	.089742	.095803	.102353	.109422
.117038	.125229	.134017	.143422	.153456	.164123	.175415	.187311	.199774	.212744
.226137	.239843	.253717	.267581	.281218	.294378	.308768	.318078	.327987	.336108
.342189	.345954	.347231	.345959	.342202	.336127	.327991	.318105	.306801	.294413
.281258	.267623	.253763	.239891	.226188	.212797	.199830	.187370	.175478	.164187
.153524	.143493	.134092	.125308	.117121	.109509	.102445	.095900	.089843	.084246
.079078	.074310	.069914	.065863	.062131	.058695	.055532	.052620	.049940	.047475
.045207	.043120	.041202	.039439	.037819	.036331	.034965	.033713	.032565	.031518
.030556	.029682	.028887	.028186	.027514	.026929	.026405	.025940	.025530	.025174
.024870	.024614	.024407	.024245	.024130	.024059	.024031	.024048	.024107	.024210
.024357	.024549	.024786	.025069	.025399	.025778	.026207	.026688	.027224	.027817
.028470	.029185	.029966	.030818	.031740	.032741	.033824	.034994	.036258	.037618
.039079	.040653	.042343	.044158	.046103	.048188	.050420	.052807	.055358	.058081
.060985	.064078	.067368	.070862	.074567	.078489	.082632	.086999	.091591	.096405
.101438	.106880	.112118	.117736	.123510	.129412	.135406	.141449	.147491	.153478
.159338	.165005	.170400	.175439	.180039	.184114	.187582	.190369	.192410	.193658
.194077	.193861	.192419	.190381	.187599	.184135	.180063	.175488	.170432	.165040
.159377	.153518	.147537	.141497	.135457	.129467	.123568	.117798	.112183	.106748
.101510	.096481	.091870	.087082	.082719	.078679	.074862	.070961	.067471	.064188
.061097	.058198	.055460	.052933	.050551	.048323	.046243	.044302	.042492	.040807
.039238	.037779	.036423	.035185	.033999	.032920	.031923	.031003	.030155	.029377
.028663	.028012	.027420	.026883	.026400	.025969	.025586	.025250	.024961	.024715
.024512	.024351	.024232	.024152	.024111	.024111	.024149	.024227	.024343	.024499
.024695	.024930	.025207	.025526	.025887	.026291	.026741	.027237	.027782	.028375
.029021	.029719	.030473	.031285	.032156	.033091	.034090	.035157	.036294	.037505
.038792	.040157	.041605	.043137	.044758	.046468	.048267	.050162	.052153	.054242
.056428	.058712	.061094	.063571	.066142	.068802	.071547	.074370	.077263	.080218
.083221	.086260	.089318	.092380	.095424	.098429	.101371	.104224	.106983	.109558
.111982	.114205	.116200	.117941	.119402	.120563	.121406	.121918	.122091	.121921
.121412	.120572	.119415	.117957	.116219	.114228	.112007	.109588	.106994	.104258
.101407	.098468	.095466	.092425	.089386	.086310	.083274	.080273	.077321	.074431
.071810	.068868	.066210	.063842	.061187	.058788	.056506	.054322	.052236	.050246
.048353	.046553	.044848	.043228	.041697	.040250	.038885	.037598	.036388	.035250
.034182	.033181	.032244	.031370	.030554	.029798	.029092	.028440	.027838	.027285
.026778	.026316	.025897	.025520	.025183	.024885	.024626	.024403	.024217	.024067
.023951	.023869	.023821	.023807	.023826	.023878	.023963	.024081	.024233	.024417
.024638	.024888	.025175	.025496	.025853	.026247	.026677	.027145	.027652	.028197
.028783	.029411	.030080	.030793	.031549	.032351	.033199	.034094	.035037	.036028
.037088	.038158	.039297	.040487	.041727	.043017	.044358	.045742	.047178	.048655
.050178	.051738	.053336	.054987	.056626	.058308	.060007	.061717	.063430	.065139
.066833	.068505	.070143	.071738	.073278	.074752	.076149	.077456	.078682	.079758
.080731	.081573	.082274	.082828	.083228	.083471	.083552	.083473	.083232	.082834
.082282	.081583	.080744	.079773	.078680	.077475	.076170	.074775	.073303	.071785
.070171	.068535	.066865	.065172	.063465	.061753	.060044	.058346	.056665	.055008
.053378	.051778	.050217	.048698	.047217	.045783	.044398	.043058	.041765	.040524
.039332	.038190	.037098	.036054	.035060	.034113	.033213	.032359	.031551	.030787
.030086	.029387	.028749	.028151	.027592	.027071	.026588	.026138	.025724	.025344
.024998	.024684	.024402	.024150	.023929	.023737	.023575	.023441	.023335	.023257
.023207	.023184	.023188	.023219	.023276	.023360	.023471	.023608	.023772	.023963
.024180	.024424	.024696	.024995	.025321	.025678	.026058	.026468	.026908	.027376
.027872	.028398	.028954	.029539	.030154	.030798	.031471	.032174	.032906	.033667
.034456	.035273	.036117	.036986	.037880	.038797	.039737	.040696	.041673	.042665
.043670	.044686	.045708	.046733	.047758	.048779	.049791	.050790	.051770	.052728
.053658	.054654	.055412	.056225	.056990	.057700	.058350	.058937	.059455	.059901
.060270	.060581	.060772	.060898						

S(N) ANALYSIS - 80 EVENLY SPACED FREQUENCIES

FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)	FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)
.06670	.1	.578176	5.062953	2.73470	4.1	.215442	.010885
.13340	.2	.096558	1.628942	2.80140	4.2	.092213	.010264
.20010	.3	.039951	.832057	2.86810	4.3	.044355	.009869
.26680	.4	.025202	.515859	2.93480	4.4	.028031	.009498
.33350	.5	.021881	.355874	3.00150	4.5	.024030	.009149
.40020	.6	.025491	.262713	3.06820	4.6	.027692	.008820
.46690	.7	.041346	.203233	3.13490	4.7	.041850	.008510
.53360	.8	.107788	.162705	3.20160	4.8	.076108	.008216
.60030	.9	.681794	.133718	3.26830	4.9	.142660	.007939
.66700	1.0	9.663900	.112190	3.33500	5.0	.194078	.007676
.73370	1.1	.681810	.095717	3.40170	5.1	.142706	.007427
.80040	1.2	.107832	.082799	3.46840	5.2	.076204	.007190
.86710	1.3	.041436	.072461	3.53510	5.3	.041804	.006965
.93380	1.4	.025677	.064043	3.60180	5.4	.027889	.006752
1.00050	1.5	.022298	.057087	3.66850	5.5	.024111	.006548
1.06720	1.6	.028328	.051266	3.73520	5.6	.027134	.006355
1.13390	1.7	.043828	.046340	3.80190	5.7	.038266	.006170
1.20060	1.8	.114215	.042130	3.86860	5.8	.062073	.005994
1.26730	1.9	.518341	.038500	3.93530	5.9	.099024	.005825
1.33400	2.0	2.147127	.035345	4.00200	6.0	.122090	.005664
1.40070	2.1	.518370	.032585	4.06870	6.1	.099061	.005511
1.46740	2.2	.114290	.030154	4.13540	6.2	.062146	.005363
1.53410	2.3	.043979	.028001	4.20210	6.3	.038362	.005222
1.60080	2.4	.026836	.026084	4.26880	6.4	.027180	.005087
1.66750	2.5	.022955	.024368	4.33550	6.5	.023821	.004957
1.73420	2.6	.027208	.022827	4.40220	6.6	.026165	.004833
1.80090	2.7	.045032	.021435	4.46890	6.7	.034653	.004713
1.86760	2.8	.106958	.020174	4.53560	6.8	.050795	.004598
1.93430	2.9	.338193	.019028	4.60230	6.9	.072050	.004487
2.00100	3.0	.744016	.017983	4.66900	7.0	.083552	.004381
2.06770	3.1	.338235	.017027	4.73570	7.1	.072077	.004279
2.13440	3.2	.107057	.016149	4.80240	7.2	.050838	.004180
2.20110	3.3	.045221	.015342	4.86910	7.3	.034676	.004085
2.26780	3.4	.027558	.014597	4.93580	7.4	.026053	.003994
2.33450	3.5	.023604	.013909	5.00250	7.5	.023208	.003905
2.40120	3.6	.027722	.013271	5.06920	7.6	.024932	.003820
2.46790	3.7	.044183	.012679	5.13590	7.7	.031197	.003738
2.53460	3.8	.092105	.012127	5.20260	7.8	.042067	.003658
2.60130	3.9	.215395	.011614	5.26930	7.9	.054729	.003581
2.66800	4.0	.347231	.011134	5.33600	8.0	.060940	.003507

SPECTRAL DENSITY FOR 20 DIVISIONS OF LOWEST FREQUENCY BAND
FREQUENCIES

.003335	.006670	.010005	.013340	.016675	.020010	.023345	.026680	.030015	.033350
.036685	.040020	.043355	.046690	.050025	.053360	.056695	.060030	.063365	.066700
S(N)									
48.90	42.48	34.10	25.86	19.01	13.85	10.13	7.49	5.61	4.27
3.30	2.58	2.05	1.65	1.35	1.11	.93	.79	.67	.58

SUMS OF S(N) FOR THE TWO SERIES 20.17 226.70

VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.1012 (M/S)**2

LENGTH SCALE FROM INTEGRATION OF ACF IS 57.3 M

VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM

S(N)C, - (M/S)**2

.7683	.7603	.2363	.1200	.0754	.0530	.0400
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RMS
 .8765 .8720 .4881 .3484 .2746 .2303 .1999
 SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
 .5600 .0832 .0237 .0119 .0074 .0051 .0037
 VARIANCES FOR FIRST HALF-P AND FOR 8P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .7303 .5893 .2244 .1190 .0753 .0530 .0400
 SPECTRAL ESTIMATES FROM SIMULATED DATA
 FIRST NUMBER IS SERIES MEAN

.0000	45.6637	33.0287	20.9659	12.7974	7.9214	5.0578	3.3484	2.2954	1.6286
1.1925	.8994	.6969	.5531	.4486	.3706	.3113	.2652	.2286	.1992
.1751	.1553	.1386	.1245	.1124	.1021	.0931	.0853	.0785	.0724
.0671	.0624	.0582	.0545	.0511	.0481	.0454	.0430	.0408	.0388
.0370	.0353	.0338	.0325	.0313	.0302	.0291	.0282	.0274	.0266
.0259	.0253	.0248	.0243	.0238	.0234	.0231	.0228	.0225	.0223
.0222	.0220	.0219	.0219	.0219	.0219	.0220	.0221	.0222	.0224
.0226	.0229	.0232	.0236	.0240	.0245	.0250	.0256	.0263	.0270
.0278	.0287	.0297	.0308	.0320	.0333	.0347	.0363	.0381	.0401
.0423	.0447	.0474	.0504	.0538	.0576	.0619	.0667	.0722	.0785
.0857	.0940	.1035	.1147	.1277	.1431	.1612	.1829	.2089	.2402
.2783	.3250	.3826	.4541	.5434	.6560	.7986	.9806	1.2144	1.5163
1.9082	2.4190	3.0855	3.9517	5.0598	6.4171	7.9047	9.1589	9.6639	9.1595
7.9055	6.4176	5.0804	3.9522	3.0858	2.4192	1.9083	1.5163	1.2144	.9806
.7986	.6559	.5434	.4540	.3825	.3250	.2783	.2402	.2088	.1829
.1612	.1431	.1277	.1147	.1038	.0940	.0857	.0785	.0722	.0667
.0619	.0576	.0538	.0505	.0474	.0447	.0423	.0402	.0382	.0364
.0348	.0334	.0321	.0309	.0298	.0288	.0280	.0272	.0264	.0258
.0252	.0247	.0242	.0238	.0235	.0232	.0229	.0227	.0226	.0224
.0223	.0223	.0223	.0223	.0224	.0226	.0227	.0229	.0232	.0235
.0238	.0243	.0247	.0252	.0258	.0265	.0272	.0280	.0289	.0299
.0309	.0321	.0335	.0349	.0365	.0383	.0402	.0424	.0448	.0475
.0505	.0538	.0575	.0617	.0663	.0715	.0774	.0841	.0916	.1002
.1100	.1211	.1338	.1484	.1652	.1845	.2069	.2327	.2626	.2974
.3377	.3846	.4391	.5025	.5760	.6611	.7593	.8720	1.0003	1.1449
1.3052	1.4788	1.6601	1.8383	1.9954	2.1065	2.1471	2.1066	1.9956	1.8385
1.6803									

VARIANCE OF S(N)R FROM SIMULATED DATA 1.8559
 SMOM(1), SMOM(2) .0000 1.8559
 SKEWNESS AND KURTOSIS -.0028 2.8664
 HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED
 24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE
 BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ), NS(N), HARMONIC COUNT PER BAND [NS(N):ORIG	SIM	VK	VKA]
4.75571 5.33600 4.23854 211 814 1024	.20405	.01660	.02017
3.77780 4.23854 3.36679 168 647 814	.25255	.01934	.02349
3.00065 3.36679 2.67434 134 514 647	.29936	.02253	.02737
2.38350 2.67434 2.12430 106 409 514	.21676	.02623	.03186
1.89328 2.12430 1.68739 85 325 409	.46728	.03053	.03708
1.50389 1.68739 1.34034 68 258 325	.45495	.03560	.04325
1.19458 1.34034 1.06467 54 205 258	.54066	.04152	.05044
.94889 1.06467 .84570 43 163 205	.02729	.04836	.05875
.75373 .84570 .67176 34 130 163	1.08427	.05616	.06821
.59871 .67176 .53360 28 103 130	1.43605	.06539	.07942
.47557 .53360 .42385 22 82 103	.02512	.07627	.09263
.37776 .42385 .33668 17 66 82	.00916	.08780	.10661

.30007	.33668	.26743	15	52	66	.00689	.00689	.10192	.12374
.23035	.26743	.21243	11	42	52	.00706	.00706	.11799	.14319
.18933	.21243	.16874	10	33	42	.00856	.00856	.13687	.16601
.15039	.16874	.13403	7	27	33	.01111	.01111	.15702	.19029
.11946	.13403	.10647	7	21	27	.01538	.01538	.18162	.21979
.09489	.10647	.08457	5	17	21	.02238	.02238	.21167	.25562
.07537	.08457	.06718	4	14	17	.03172	.03172	.23501	.28297
.05987	.06718	.05336	4	11	14	.05002	.05002	.26717	.32014
.04756	.05336	.04239	3	9	11	.08111	.08111	.30399	.36166
.03778	.04239	.03367	3	7	9	.13475	.13475	.34769	.40890
.03001	.03367	.02674	2	6	7	.19473	.19473	.37895	.43953
.02384	.02674	.02124	2	5	6	.24692	.24692	.39002	.44494

UNBANDIED NSN SPECTRA

.005211	.237951	.237951	.303072	.286604
.010422	.344222	.344221	.390048	.405191
.015633	.327756	.327755	.400656	.439214

ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT

A, B, AMP, ANGLE IN DEGREES - .3000 - .0765 .3174 -166.0499

PHASE ANGLE FOR 1P IN SIMULATED DATA -166.0 DEGREES

OFFSET ANGLE BETWEEN MEAN WIND AND TURBULENCE AT 1P (DELAY) .0 DEGREES

OFFSET, IFFSET, -7.4 11

ONE CYCLE OF MEAN WIND EFFECT - M/S

8.66 8.48 8.66 9.09 9.58 10.00 10.33 10.57 10.71 10.76 10.71 10.57 10.33 10.00 9.58 9.09

NUMBER OF COMPLETE MEAN WIND CYCLES IN SIMULATION 128

VARIANCES FOR FIRST HALF-P AND FOR 6P FROM

SPECTRUM OF SIMULATED DATA, S(N)R

.7303	1.5054	.2144	.1189	.0760	.0531	.0400
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SPECTRAL ESTIMATES FROM SIMULATED DATA

FIRST NUMBER IS SERIES MEAN

9.8203	45.6837	33.0287	20.9859	12.7974	7.9214	5.0578	3.3484	2.2954	1.8286
1.1925	.8994	.6989	.5531	.4486	.3706	.3113	.2652	.2286	.1992
.1751	.1553	.1386	.1245	.1124	.1021	.0931	.0853	.0785	.0724
.0671	.0624	.0582	.0545	.0511	.0481	.0454	.0430	.0408	.0388
.0370	.0353	.0338	.0325	.0313	.0302	.0291	.0282	.0274	.0266
.0259	.0253	.0248	.0243	.0238	.0234	.0231	.0228	.0225	.0223
.0222	.0220	.0219	.0219	.0219	.0219	.0220	.0221	.0222	.0224
.0228	.0229	.0232	.0236	.0240	.0245	.0250	.0256	.0263	.0270
.0278	.0287	.0297	.0308	.0320	.0333	.0347	.0363	.0381	.0401
.0423	.0447	.0474	.0504	.0538	.0578	.0619	.0667	.0722	.0785
.0857	.0940	.1035	.1147	.1277	.1431	.1612	.1829	.2089	.2402
.2783	.3250	.3826	.4541	.5434	.6580	.7986	.9806	1.2144	1.5183
1.9002	2.4190	3.0855	3.9517	5.0598	6.4171	7.9047	9.1589	109.3058	9.1595
7.9055	6.4179	5.0805	3.9522	3.0858	2.4192	1.9083	1.5183	1.2144	.9806
.7986	.6559	.5434	.4540	.3825	.3250	.2783	.2402	.2088	.1829
.1612	.1431	.1277	.1147	.1036	.0940	.0857	.0785	.0722	.0667
.0619	.0576	.0538	.0505	.0474	.0447	.0423	.0402	.0382	.0364
.0348	.0334	.0321	.0309	.0298	.0288	.0280	.0272	.0264	.0258
.0252	.0247	.0242	.0238	.0235	.0232	.0229	.0227	.0226	.0224
.0223	.0223	.0223	.0223	.0224	.0226	.0227	.0229	.0232	.0235
.0238	.0243	.0247	.0252	.0258	.0265	.0272	.0280	.0289	.0299
.0309	.0321	.0335	.0349	.0365	.0383	.0402	.0424	.0448	.0475
.0505	.0538	.0575	.0617	.0663	.0715	.0774	.0841	.0916	.1002
.1100	.1211	.1338	.1484	.1652	.1845	.2069	.2327	.2626	.2974
.3377	.3846	.4391	.5025	.5760	.6611	.7593	.8720	1.0003	1.1449
1.3052	1.4788	1.6601	1.8383	1.9954	2.1065	.2254	2.1068	1.9956	1.8385

1.6803
 VARIANCE OF S(N)R FROM SIMULATED DATA 2.7808
 SMOM(1), SMOM(2) 9.8203 2.7808
 SKEWNESS AND KURTOSIS -.0535 2.7323
 HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED
 24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE
 BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ), NS(N), HARMONIC COUNT PER BAND [NS(N):ORIG	SIM	VK	VKA]
4.75571 5.33600 4.23854 211 814 1024 .20405	.20401	.01660	.02017
3.77760 4.23854 3.36679 168 647 814 .25255	.25268	.01934	.02349
3.00065 3.36679 2.67434 134 514 647 .29936	.29965	.02253	.02737
2.38350 2.67434 2.12430 106 409 514 .21676	.21972	.02623	.03186
1.89328 2.12430 1.68739 85 325 409 .46728	.45852	.03053	.03708
1.50389 1.68739 1.34034 68 258 325 .45495	.45495	.03560	.04325
1.19458 1.34034 1.06467 54 205 258 .54066	.49815	.04152	.05044
.94889 1.06467 .84570 43 163 205 .02729	.02729	.04636	.05875
.75373 .84570 .67176 34 130 163 1.08427	1.08427	.05616	.06821
.59871 .67176 .53360 28 103 130 1.43605	5.27723	.06539	.07942
.47557 .53360 .42385 22 82 103 .02512	.02512	.07627	.09263
.37776 .42385 .33668 17 66 82 .00916	.00916	.08780	.10661
.30007 .33668 .26743 15 52 66 .00689	.00689	.10192	.12374
.23835 .26743 .21243 11 42 52 .00706	.00706	.11799	.14319
.18933 .21243 .16874 10 33 42 .00856	.00856	.13687	.16601
.15039 .16874 .13403 7 27 33 .01111	.01111	.15702	.19029
.11948 .13403 .10647 7 21 27 .01538	.01538	.18162	.21979
.09489 .10647 .08457 5 17 21 .02238	.02238	.21167	.25562
.07537 .08457 .06718 4 14 17 .03172	.03172	.23501	.28297
.05987 .06718 .05336 4 11 14 .05002	.05002	.26717	.32014
.04758 .05336 .04239 3 9 11 .08111	.08111	.30399	.36166
.03778 .04239 .03367 3 7 9 .13475	.13475	.34769	.40890
.03001 .03367 .02674 2 6 7 .19473	.19473	.37895	.43953
.02384 .02674 .02124 2 5 6 .24692	.24692	.39002	.44494

UNBANDED NSN SPECTRA

.005211 .237951 .237951 .303072 .286604
.010422 .344222 .344221 .390046 .405191
.015633 .327756 .327755 .400656 .439214

E.3 SERIES.DAT FOR FULL-RADIUS TURBULENCE

2048	1.753488	2.465075E-01	-2.020277E-01	2.045692
1.617282	7.430141E-01	1.021247	1.871400	
3.307503	1.371922	6.826206E-01	2.170991	
1.914813	6.678327E-01	1.044866E-01	1.209229	
1.643888	1.623982	7.937519E-02	1.694163	
2.094727	2.233690	7.987343E-01	2.149475	
1.485769	1.358942	2.426997E-01	1.770404	
2.189775	1.229862	1.513661E-01	7.370123E-01	
1.916958	1.546192	3.809394E-01	6.684520E-01	
1.429579	4.956247E-01	3.276957E-01	8.092316E-01	
1.682041	4.172747E-01	6.838059E-01	1.977336	
2.855364	1.162126	-6.752046E-01	4.154703E-01	
1.570212	9.570135E-01	7.064550E-01	8.611938E-02	
-1.107265	-1.027640	6.256020E-01	1.088885	
1.318149	2.941341E-01	9.696435E-01	1.097009	
1.400314	1.090169	-4.308353E-01	9.355078E-01	
6.188315E-01	-3.192392E-01	8.467776E-01	3.741993E-01	
-1.115180	-1.343440	-1.113358	-6.429547E-02	
5.242541E-01	2.095070E-01	1.634903	1.198434	
2.631390E-01	6.920761E-01	4.575919E-01	-3.914395E-02	
-7.033716E-01	-8.025213E-01	6.966186E-01	1.336287E-01	
-1.588337	-1.795429	-7.918814E-01	-4.380561E-01	
3.419953E-01	1.205286	1.727259	3.338984E-01	
7.075159E-01	1.443089	1.898539E-01	-4.058016E-01	
-1.219230	1.926920E-01	1.040402	-7.743759E-01	
-8.105719E-01	-2.811404	-2.035655	-7.292606E-01	
1.034402	9.165386E-01	9.450291E-02	-4.063768E-01	
6.254872E-01	1.174983	8.014804E-01	-5.798797E-01	
-2.155171	-7.347254E-01	1.552579E-01	-4.698346E-01	
-5.334645E-01	-1.642969	-1.904534	-5.200955E-01	
-3.275743E-01	6.007791E-03	4.551721E-01	8.322967E-01	
6.049472E-01	1.584181E-01	8.718157E-02	-2.692000E-01	
-1.817746	-4.102403E-01	7.773871E-01	-7.583367E-01	
-1.297451E-01	-5.293402E-01	-1.576496	4.875388E-01	
-4.026513E-01	2.137615E-01	3.101786E-01	1.034484	
3.721474E-01	-8.412769E-01	2.721140E-01	-1.351159	
-1.901999	2.974114E-01	1.445090	-6.523440E-01	
6.919290E-01	6.033468E-01	-4.594467E-01	3.676523E-01	
5.082237E-01	-4.495671E-01	-3.233606E-01	-5.176415E-01	
-1.045944E-01	-8.308401E-01	-6.794058E-01	-3.602970E-01	
-8.667946E-01	-3.893042E-01	-2.272195E-02	1.723622E-01	
1.592250E-01	3.275765E-01	9.793259E-01	6.247334E-01	
7.320047E-01	-1.921768E-02	-1.295225	-1.486122	
-1.119025	-1.901425	-9.874387E-01	5.427682E-01	
2.838044E-01	3.542667E-01	-2.808845E-01	-6.442095E-01	
4.004532E-01	3.074192E-01	7.882807E-01	6.956215E-01	
6.293409E-01	-1.360977	-1.711572	-8.018059E-01	
-9.826750E-01	-9.910877E-01	-5.573839E-01	1.094395	
6.730292E-01	9.367424E-02	4.198298E-01	-8.495193E-01	

2048	10.417360	8.725678	8.461849	11.140250
11.192670	10.743010	11.354630	12.440490	
14.016310	12.126970	11.391430	12.740080	
12.248200	10.667830	9.679873	10.303790	
10.307760	10.103130	8.743252	10.788730	
11.670110	12.233690	11.132120	12.718570	
12.194580	12.113990	10.951510	12.339500	
12.523160	11.229860	9.726752	9.831574	
10.580830	10.025360	9.044816	9.763015	
11.004960	10.495620	10.681080	11.378320	
12.390850	11.172320	11.392620	12.546430	
13.188750	11.162130	8.900182	9.510033	
10.234090	9.436181	9.370332	9.180682	
8.468121	8.972360	10.958990	11.657980	
12.026960	11.049180	11.678450	11.668100	
11.739700	11.090170	9.144550	10.030070	
9.282707	8.159928	9.510654	9.468781	
8.460206	8.656560	9.220026	10.504800	
11.233060	10.964550	12.343710	11.767530	
10.596520	10.692080	10.032980	9.055419	
7.880504	7.676647	9.360496	9.228191	
7.987049	8.204571	9.541703	10.131040	
11.050810	11.960330	12.438070	10.902990	
11.120900	11.443090	9.765240	8.688701	
7.444845	8.671860	9.704279	8.320187	
8.764814	7.188596	8.297729	9.839832	
11.743210	11.671590	10.803310	10.162720	
10.958870	11.174980	10.376870	8.514683	
6.500705	7.744442	8.819135	8.624728	
9.041922	8.357031	8.428850	10.049000	
10.381240	10.761050	11.163980	11.401390	
10.938330	10.158420	9.682567	8.825361	
6.846129	8.068928	9.441263	8.336226	
9.445641	9.470660	8.756888	11.056630	
10.226160	10.968810	11.018990	11.603580	
10.705530	9.158723	9.847500	7.743403	
6.761877	8.776579	10.108970	8.442219	
10.267310	10.603350	9.873938	10.936740	
11.297030	10.305480	10.385450	10.051450	
10.148790	9.169160	8.895980	8.734265	
7.797081	8.089864	8.641154	9.266925	
9.734812	10.327580	11.312710	11.193830	
11.440900	10.735830	9.413586	9.082971	
9.214359	8.098575	8.587948	9.637331	
8.947760	8.833435	8.382992	8.450353	
9.975840	10.367420	11.121670	11.264710	
11.338150	9.394070	8.997239	9.767287	
9.350710	9.008912	9.018003	10.188960	
9.336905	8.572843	9.083706	8.245043	
9.666586	10.694110	11.911420	11.399260	
10.240620	9.048352	8.623897	8.314447	
8.905122	9.327270	8.646326	10.450980	
8.839531	8.839749	9.969227	8.168791	
8.815277	9.360313	11.835090	11.751490	
11.190910	9.105966	8.880075	7.810741	

9.268798	10.446800	9.134673	10.926040
9.749838	9.908879	9.957315	8.525487
9.051566	9.292163	11.061970	11.452890
10.056980	9.335231	9.257263	7.648871
8.199860	8.268799	9.552810	10.606290
9.935897	9.551849	9.545115	8.303308
9.527249	10.194180	10.767280	11.460110
10.396350	10.162420	8.932281	8.784277
9.285255	8.148023	9.855658	10.179960
9.879848	9.546544	9.321956	8.521698
8.888187	10.311140	10.324290	10.751500
10.337430	9.143222	8.574186	9.697090
10.079590	9.827757	9.137015	10.114330
8.394199	8.950130	8.278121	7.736305
9.364507	11.309740	9.781417	10.304060
11.292340	8.711020	9.318501	10.037820
10.172360	9.906736	10.004210	9.575739
8.633182	7.457995	7.188704	8.308779
9.813901	11.065940	10.877110	9.389503
11.850860	10.506800	9.373713	10.080080
10.118600	9.624273	9.802213	8.789554
8.526304	6.772142	5.908778	8.891724
10.591820	10.965020	10.790430	10.370430
11.566820	10.951790	11.171050	10.288120
9.797547	9.167178	8.729464	8.539022
8.357395	6.196500	7.145839	8.375730
10.244590	10.751100	10.777010	11.167370
11.013470	10.271890	10.794310	10.654870
10.847740	9.300635	8.773454	8.060921
8.048702	6.986992	6.713470	7.862880
9.020002	10.293360	10.168780	10.205920
9.617628	9.377049	10.478470	10.983510

APPENDIX F

SAMPLE OUTPUT FROM ALL FILES FOR THE 34-M VAWT CASE
FOR THE TANGENTIAL AND RADIAL WIND COMPONENTS
AT THE EQUATORIAL LOCATION OF A BLADE

F.1 SUMMARY.BRF TANGENTIAL

VAWT TANGENTIAL SIMULATION
 SERIAL NUMBER VAWTT
 RADIUS OF ROTATION 17.0 M
 RATE OF ROTATION .5000 HZ
 HUB HEIGHT 29.0 M
 SURFACE ROUGHNESS LENGTH .0500 M
 MEAN WIND SPEED 10.00 M/S
 TURBULENCE RMS VALUES
 U-COMPONENT 1.509 M/S
 V-COMPONENT 1.509 M/S
 TURBULENCE VARIANCES
 U-COMPONENT 2.276 (M/S)**2
 V-COMPONENT 2.276 (M/S)**2
 FRICTION VELOCITY .029 M/S
 TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 121.8 M
 LATERAL 48.7 M
 NUMBER DATA TO BE SIMULATED 2048
 DISCRETIZATION INTERVAL .1250 SEC
 ALIAS FACTOR 4
 ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
 MANGLE WAS READ IN - DT WAS CALCULATED
 ALFA, BETA .3489 .0281
 LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
 NUMBER OF HARMONICS IN SPECTRA 1024
 THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
 SPECTRUM AND REDUCED VERSION.
 FUNDAMENTAL FREQUENCY IS .003906 HZ

 MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
 VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.0899 (M/S)**2
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM
 S(N)C, - (M/S)**2
 .3393 1.0942 .3985 .1088 .0557 .0372 .0275
 RMS
 .5825 1.0481 .8313 .3267 .2359 .1928 .1658
 SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
 .9090 .1410 .0402 .0202 .0125 .0086 .0064
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .3582 1.1089 .3634 .1023 .0554 .0373 .0276
 VARIANCE OF S(N)R FROM SIMULATED DATA 2.0839
 SKEWNESS AND KURTOSIS -.1480 3.0006
 ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .3582 54.1260 .3634 .1023 .0554 .0373 .0276
 VARIANCE OF S(N)R FROM SIMULATED DATA 55.1011
 SKEWNESS AND KURTOSIS .0276 1.5932

F.2 SUMMARY.DAT TANGENTIAL

VAWT TANGENTIAL SIMULATION
SERIAL NUMBER VAWTT
RADIUS OF ROTATION 17.0 M
RATE OF ROTATION .5000 HZ
HUB HEIGHT 29.0 M
SURFACE ROUGHNESS LENGTH .0500 M
MEAN WIND SPEED 10.00 M/S
TURBULENCE RMS VALUES
U-COMPONENT 1.509 M/S
V-COMPONENT 1.509 M/S
TURBULENCE VARIANCES
U-COMPONENT 2.276 (M/S)**2
V-COMPONENT 2.276 (M/S)**2
FRICTION VELOCITY .029 M/S
TURBULENCE INTEGRAL LENGTH SCALES
LONGITUDINAL 121.0 M
LATERAL 48.7 M
NUMBER DATA TO BE SIMULATED 2048
DISCRETIZATION INTERVAL .1250 SEC
ALIAS FACTOR 4
ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
ANGLE WAS READ IN - DT WAS CALCULATED
ALFA, BETA .3489 .0261
LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
NUMBER OF HARMONICS IN SPECTRA 1024
THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
SPECTRUM AND REDUCED VERSION.
FUNDAMENTAL FREQUENCY IS .003906 HZ

MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
DIFFERENT FORMS OF VARIABLES:
- ORIGINAL
-A - INCLUDING EXTENSIONS ASSOCIATED WITH ALIAS REMOVAL
-ND - DIMENSIONLESS VARIABLE
-AND - BOTH OF THE ABOVE
DISCRETIZATION INTERVAL - DT
.125 SEC
-A .031 SEC
-ND .198
-AND .049
NUMBER OF SIMULATED DATA - NMT
2048
-A 8192
FUNDAMENTAL FREQUENCY - EN1
.00391 HZ
-ND .00249
NYQUIST FREQUENCY - EN2
4.00000 HZ
-A 16.00000 HZ

ND 2.54848
 AND 10.18592
 NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE
 16
 A 84
 ANGLEA 1.5708
 COSA, SINA .000 1.000
 DIRECTION COSINES FOR MOVING POINT
 HANNING WINDOW USED - LAST R BEFORE USE -.0002
 AUTOCORRELATION FUNCTION 1453 STEPS 45.41 SECONDS
 AFTER FIRST VALUE SKIP INTERVAL IS 2

.8987	.7742	.6506	.5237	.3980	.2787	.1705	.0767	-.0005	-.0611	-.1060	-.1374	-.1579	-.1704	-.1776
-.1813	-.1828	-.1824	-.1795	-.1728	-.1597	-.1384	-.1063	-.0611	-.0016	.0729	.1615	.2617	.3689	.4749
.5654	.6200	.6251	.5817	.5031	.4073	.3077	.2126	.1275	.0554	-.0027	-.0469	-.0785	-.0997	-.1128
-.1203	-.1242	-.1261	-.1269	-.1270	-.1259	-.1223	-.1146	-.1009	-.0790	-.0471	-.0037	.0515	.1179	.1926
.2707	.3443	.4031	.4373	.4412	.4147	.3635	.2968	.2244	.1539	.0906	.0374	-.0047	-.0359	-.0574
-.0709	-.0786	-.0823	-.0838	-.0844	-.0848	-.0852	-.0853	-.0841	-.0802	-.0721	-.0580	-.0363	-.0057	.0340
.0822	.1364	.1924	.2443	.2851	.3086	.3113	.2932	.2575	.2103	.1583	.1072	.0613	.0231	-.0065
-.0277	-.0414	-.0493	-.0529	-.0540	-.0538	-.0534	-.0535	-.0542	-.0551	-.0556	-.0545	-.0505	-.0421	-.0281
-.0073	.0204	.0545	.0931	.1330	.1697	.1984	.2148	.2167	.2038	.1786	.1450	.1079	.0714	.0388
.0122	-.0079	.0215	-.0295	-.0333	-.0341	-.0333	-.0320	-.0310	-.0309	-.0317	-.0332	-.0348	-.0356	-.0345
-.0303	-.0219	-.0086	.0102	.0337	.0607	.0887	.1146	.1347	.1462	.1474	.1382	.1204	.0966	.0704
.0448	.0222	.0042	-.0088	-.0168	-.0208	-.0217	-.0206	-.0186	-.0166	-.0152	-.0150	-.0159	-.0177	-.0200
-.0220	-.0229	-.0216	-.0173	-.0093	.0028	.0186	.0370	.0564	.0744	.0884	.0963	.0971	.0906	.0780
.0614	.0431	.0255	.0103	-.0014	-.0092	-.0133	-.0145	-.0135	-.0112	-.0085	-.0061	-.0046	-.0043	-.0052
-.0071	-.0098	-.0125	-.0146	-.0153	-.0138	-.0095	-.0022	.0079	.0202	.0334	.0456	.0553	.0607	.0612
.0506	.0479	.0364	.0239	.0120	.0022	-.0050	-.0092	-.0107	-.0100	-.0078	-.0048	-.0018	.0006	.0022
.0025	.0017	-.0003	-.0030	-.0081	-.0089	-.0107	-.0111	-.0094	-.0054	.0008	.0087	.0174	.0258	.0322
.0359	.0361	.0329	.0269	.0191	.0107	.0030	-.0031	-.0071	-.0088	-.0086	-.0068	-.0040	-.0008	.0022
.0046	.0061	.0064	.0056	.0038	.0011	-.0020	-.0050	-.0075	-.0089	-.0089	-.0071	-.0038	.0012	.0068
.0122	.0165	.0190	.0191	.0170	.0129	.0077	.0023	-.0028	-.0081	-.0080	-.0082	-.0070	-.0048	-.0016
.0015	.0044	.0066	.0080	.0083	.0078	.0059	.0034	.0005	-.0025	-.0053	-.0072	-.0081	-.0078	-.0061
-.0033	.0002	.0036	.0064	.0080	.0081	.0067	.0040	.0006	-.0028	-.0057	-.0075	-.0081	-.0074	-.0056
-.0031	-.0002	.0027	.0053	.0073	.0085	.0088	.0081	.0066	.0045	.0018	-.0010	-.0037	-.0050	-.0072
-.0076	-.0071	-.0056	-.0036	-.0015	.0003	.0013	.0014	.0004	-.0013	-.0035	-.0055	-.0071	-.0078	-.0076
-.0064	-.0045	-.0021	.0006	.0032	.0054	.0071	.0081	.0083	.0078	.0065	.0047	.0024	-.0001	-.0026
-.0047	-.0062	-.0070	-.0071	-.0065	-.0054	-.0041	-.0030	-.0024	-.0024	-.0030	-.0041	-.0054	-.0065	-.0073
-.0074	-.0067	-.0054	-.0036	-.0014	.0009	.0031	.0050	.0064	.0072	.0074	.0069	.0059	.0043	.0024
.0003	-.0018	-.0037	-.0052	-.0061	-.0065	-.0064	-.0059	-.0051	-.0045	-.0041	-.0041	-.0045	-.0051	-.0059
-.0065	-.0067	-.0065	-.0057	-.0045	-.0028	-.0009	.0010	.0027	.0043	.0054	.0060	.0062	.0058	.0050
.0037	.0022	.0005	-.0013	-.0028	-.0042	-.0051	-.0056	-.0057	-.0055	-.0051	-.0048	-.0045	-.0045	-.0047
-.0051	-.0055	-.0058	-.0058	-.0054	-.0046	-.0035	-.0021	-.0006	.0009	.0023	.0034	.0043	.0048	.0049
.0046	.0040	.0030	.0018	.0005	-.0009	-.0021	-.0032	-.0041	-.0046	-.0048	-.0047	-.0045	-.0043	-.0042
-.0042	-.0043	-.0045	-.0047	-.0048	-.0048	-.0042	-.0036	-.0027	-.0018	-.0004	.0007	.0018	.0026	.0033
.0036	.0037	.0035	.0030	.0023	.0014	.0004	-.0006	-.0016	-.0024	-.0031	-.0035	-.0037	-.0037	-.0037
-.0035	-.0035	-.0034	-.0035	-.0036	-.0037	-.0037	-.0035	-.0032	-.0026	-.0019	-.0011	-.0003	.0005	.0013
.0019	.0023	.0026	.0026	.0025	.0021	.0016	.0010	.0003	-.0004	-.0011	-.0017	-.0022	-.0025	-.0027
-.0027	-.0027	-.0027	-.0026	-.0026	-.0026	-.0027	-.0027	-.0026	-.0025	-.0022	-.0018	-.0013	-.0008	-.0002
.0004	.0009	.0013	.0016	.0017	.0018	.0017	.0014	.0011	.0007	.0002	-.0003	-.0007	-.0011	-.0014
-.0017	-.0018	-.0019	-.0019	-.0018	-.0018	-.0018	-.0018	-.0018	-.0018	-.0017	-.0016	-.0014	-.0012	-.0008
-.0005	-.0001	.0002	.0005	.0008	.0010	.0011	.0011	.0010	.0009	.0007	.0004	.0001	-.0002	-.0004
-.0007	-.0009	-.0010	-.0011	-.0011	-.0011	-.0011	-.0011	-.0011	-.0011	-.0011	-.0011	-.0010	-.0009	-.0008
-.0007	-.0005	-.0003	-.0001	.0001	.0003	.0004	.0005	.0006	.0006	.0005	.0005	.0004	.0002	.0001
-.0001	-.0002	-.0004	-.0005	-.0005	-.0006	-.0006	-.0006	-.0006	-.0006	-.0005	-.0005	-.0005	-.0005	-.0005
-.0005	-.0004	-.0003	-.0002	-.0001	-.0000	.0001	.0001	.0002	.0002	.0003	.0003	.0002	.0002	.0001

.0001	.0000	-.0000	-.0001	-.0001	-.0002	-.0002	-.0002	-.0002	-.0002	-.0002	-.0002	-.0002	-.0002	-.0002
-.0002	-.0002	-.0002	-.0001	-.0001	-.0001	-.0000	-.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001
.0001	.0000	.0000	.0000	.0000	-.0000	-.0000	-.0000	-.0000	-.0000	-.0000	-.0000	-.0000	-.0000	-.0000
-.0000	-.0000	-.0000	-.0000	-.0000	-.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

VARIANCE FROM INTEGRATION OF ROTATIONAL S(M)
 COMPUTED BY FFT OF ACF 2.083947 (M/S)**2
 VON KARMAN S(N) SPECTRUM

43.831820	46.188240	44.137020	39.139900	33.497410	28.350130	24.016670	20.475000	17.603190	15.269410
13.360330	11.785360	10.474220	9.372793	8.439507	7.842220	6.955912	6.360950	5.841794	5.386038
4.983696	4.826661	4.308308	4.023178	3.766736	3.535207	3.325415	3.134675	2.960708	2.801567
2.655583	2.521316	2.397519	2.283109	2.177140	2.078784	1.987312	1.902082	1.822527	1.748141
1.678476	1.613131	1.551747	1.494004	1.439811	1.388308	1.339880	1.294052	1.250693	1.209808
1.170630	1.133821	1.098443	1.064978	1.033108	1.002735	.973762	.946103	.919678	.894412
.870236	.847087	.824908	.803638	.783233	.763643	.744824	.728735	.709338	.692596
.676477	.660950	.645984	.631552	.617629	.604169	.591211	.578873	.566555	.554837
.543501	.532531	.521911	.511828	.501860	.492002	.482637	.473554	.464741	.456187
.447882	.439817	.431981	.424368	.416963	.409784	.402763	.395950	.389320	.382866
.376581	.370459	.364495	.358683	.353018	.347494	.342108	.336854	.331727	.326724
.321841	.317074	.312418	.307871	.303428	.299088	.294845	.290698	.286644	.282679
.278802	.275008	.271297	.267865	.264110	.260630	.257223	.253888	.250618	.247417
.244281	.241208	.238198	.235244	.232350	.229513	.226730	.224002	.221325	.218699
.216122	.213594	.211113	.208678	.206287	.203939	.201634	.199371	.197148	.194964
.192819	.190711	.188640	.186604	.184604	.182637	.180704	.178803	.176935	.175097
.173289	.171511	.169763	.168042	.166349	.164684	.163045	.161432	.159844	.158281
.156742	.155227	.153736	.152267	.150820	.149396	.147993	.146610	.145249	.143907
.142585	.141283	.139999	.138734	.137487	.136258	.135046	.133852	.132674	.131513
.130368	.129239	.128126	.127027	.125944	.124875	.123821	.122781	.121755	.120743
.119744	.118758	.117785	.116825	.115877	.114941	.114018	.113108	.112208	.111317
.110440	.109573	.108717	.107872	.107038	.106214	.105399	.104595	.103801	.103016
.102240	.101474	.100717	.099969	.099230	.098500	.097778	.097065	.096359	.095662
.094973	.094292	.093619	.092954	.092295	.091645	.091001	.090365	.089738	.089114
.088499	.087890	.087289	.086693	.086105	.085522	.084946	.084378	.083812	.083255
.082703	.082157	.081618	.081082	.080552	.080029	.079511	.078998	.078490	.077988
.077491	.076999	.076511	.076029	.075552	.075079	.074611	.074148	.073689	.073235
.072785	.072340	.071899	.071462	.071030	.070601	.070177	.069757	.069341	.068929
.068521	.068118	.067716	.067319	.066926	.066536	.066150	.065768	.065389	.065014
.064642	.064274	.063909	.063547	.063188	.062833	.062481	.062132	.061786	.061443
.061103	.060767	.060433	.060102	.059774	.059449	.059127	.058807	.058490	.058178
.057865	.057558	.057250	.056947	.056648	.056347	.056051	.055758	.055467	.055178
.054892	.054608	.054327	.054048	.053771	.053497	.053224	.052954	.052688	.052420
.052157	.051895	.051638	.051378	.051123	.050870	.050619	.050369	.050122	.049878
.049633	.049391	.049152	.048914	.048678	.048444	.048211	.047980	.047752	.047524
.047299	.047075	.046853	.046633	.046414	.046197	.045982	.045768	.045558	.045345
.045138	.044928	.044722	.044518	.044315	.044113	.043913	.043714	.043517	.043321
.043127	.042934	.042742	.042552	.042363	.042175	.041989	.041804	.041620	.041438
.041257	.041077	.040899	.040721	.040545	.040370	.040197	.040024	.039853	.039683
.039514	.039348	.039179	.039014	.038849	.038686	.038524	.038362	.038202	.038043
.037885	.037728	.037572	.037418	.037264	.037111	.036959	.036808	.036658	.036510
.036362	.036215	.036069	.035924	.035779	.035636	.035494	.035353	.035212	.035072
.034934	.034798	.034659	.034523	.034388	.034253	.034120	.033987	.033855	.033724
.033593	.033464	.033335	.033207	.033080	.032954	.032828	.032704	.032579	.032456
.032334	.032212	.032091	.031970	.031851	.031732	.031614	.031498	.031379	.031263
.031148	.031033	.030919	.030805	.030693	.030581	.030469	.030358	.030248	.030139
.030030	.029922	.029814	.029707	.029601	.029495	.029390	.029285	.029181	.029078

.028975	.028873	.028771	.028670	.028569	.028469	.028370	.028271	.028173	.028075
.027978	.027881	.027785	.027690	.027594	.027500	.027406	.027312	.027219	.027127
.027035	.026943	.026852	.026762	.026672	.026582	.026493	.026404	.026316	.026229
.026142	.026055	.025969	.025883	.025797	.025712	.025628	.025544	.025460	.025377
.025295	.025212	.025130	.025049	.024968	.024887	.024807	.024727	.024648	.024569
.024491	.024412	.024335	.024257	.024180	.024104	.024028	.023952	.023876	.023801
.023727	.023653	.023579	.023505	.023432	.023359	.023287	.023215	.023143	.023071
.022900	.022930	.022859	.022789	.022720	.022650	.022581	.022513	.022445	.022377
.022309	.022242	.022175	.022108	.022042	.021976	.021910	.021844	.021779	.021715
.021650	.021586	.021522	.021459	.021395	.021332	.021270	.021207	.021145	.021083
.021022	.020961	.020900	.020839	.020779	.020719	.020659	.020599	.020540	.020481
.020422	.020364	.020306	.020248	.020190	.020133	.020076	.020019	.019962	.019906
.019850	.019794	.019738	.019683	.019628	.019573	.019518	.019464	.019410	.019356
.019302	.019249	.019196	.019143	.019090	.019038	.018985	.018933	.018882	.018830
.018779	.018728	.018677	.018628	.018576	.018525	.018475	.018426	.018376	.018327
.018278	.018229	.018180	.018131	.018083	.018035	.017987	.017939	.017892	.017844
.017797	.017750	.017704	.017657	.017611	.017565	.017519	.017473	.017428	.017382
.017337	.017292	.017247	.017203	.017158	.017114	.017070	.017026	.016982	.016939
.016895	.016852	.016809	.016766	.016724	.016681	.016639	.016597	.016555	.016513
.016472	.016430	.016389	.016348	.016307	.016266	.016225	.016185	.016145	.016105
.016065	.016025	.015985	.015946	.015906	.015867	.015828	.015789	.015750	.015712
.015673	.015635	.015597	.015559	.015521	.015483	.015448	.015408	.015371	.015334
.015297	.015260	.015224	.015187	.015151	.015114	.015078	.015042	.015006	.014971
.014935	.014900	.014864	.014829	.014794	.014759	.014725	.014690	.014655	.014621
.014587	.014553	.014519	.014485	.014451	.014417	.014384	.014351	.014317	.014284
.014261	.014218	.014185	.014153	.014120	.014088	.014056	.014023	.013991	.013960
.013928	.013896	.013864	.013833	.013802	.013770	.013739	.013708	.013677	.013647
.013616	.013585	.013555	.013524	.013494	.013464	.013434	.013404	.013374	.013345
.013315	.013288	.013258	.013227	.013198	.013169	.013140	.013111	.013082	.013053
.013025	.012998	.012968	.012940	.012911	.012883	.012855	.012827	.012800	.012772
.012744	.012717	.012689	.012662	.012635	.012608	.012581	.012554	.012527	.012500
.012474	.012447	.012421	.012394	.012368	.012342	.012318	.012289	.012264	.012238
.012212	.012186	.012161	.012135	.012110	.012084	.012059	.012034	.012009	.011984
.011959	.011934	.011909	.011885	.011860	.011835	.011811	.011787	.011762	.011738
.011714	.011690	.011668	.011642	.011618	.011595	.011571	.011548	.011524	.011501
.011477	.011454	.011431	.011408	.011385	.011362	.011339	.011316	.011293	.011271
.011248	.011226	.011203	.011181	.011158	.011136	.011114	.011092	.011070	.011048
.011026	.011004	.010982	.010961	.010939	.010918	.010898	.010875	.010853	.010832
.010811	.010790	.010769	.010748	.010727	.010706	.010685	.010664	.010644	.010623
.010602	.010582	.010562	.010541	.010521	.010501	.010480	.010460	.010440	.010420
.010400	.010381	.010361	.010341	.010321	.010302	.010282	.010263	.010243	.010224
.010204	.010185	.010166	.010147	.010128	.010109	.010090	.010071	.010052	.010033
.010014	.009996	.009977	.009958	.009940	.009921	.009903	.009884	.009868	.009848
.009830	.009812	.009793	.009775	.009757	.009739	.009722	.009704	.009688	.009668
.009650	.009633	.009615	.009598	.009580	.009563	.009545	.009528	.009511	.009494
.009476	.009459	.009442	.009425	.009408	.009391	.009374	.009358	.009341	.009324
.009307	.009291	.009274	.009258	.009241	.009225	.009208	.009192	.009176	.009159
.009143	.009127	.009111	.009095	.009079	.009063	.009047	.009031	.009015	.008999
.008984	.008968	.008952	.008936	.008921	.008905	.008890	.008874	.008859	.008844
.008828	.008813	.008798	.008783	.008767	.008752	.008737	.008722	.008707	.008692
.008677	.008662	.008648	.008633	.008618	.008603	.008589	.008574	.008559	.008545
.008530	.008516	.008501	.008487	.008473	.008458	.008444	.008430	.008416	.008401
.008387	.008373	.008359	.008345	.008331	.008317	.008303	.008290	.008276	.008262
.008248	.008234	.008221	.008207	.008194	.008180	.008166	.008153	.008139	.008126
.008113	.008099	.008086	.008073	.008059	.008046	.008033	.008020	.008007	.007994

.007981	.007988	.007955	.007942						
S(N)	ESTIMATES	FROM	FFT	OF	ACF				
7.598779	7.568624	7.426835	7.153809	6.707264	6.093070	5.365770	4.610259	3.908909	3.313691
2.837085	2.482243	2.181945	1.913813	1.705378	1.530836	1.385708	1.264282	1.160523	1.070051
.990780	.921864	.862264	.810277	.764107	.722623	.685463	.652518	.623393	.597365
.573750	.552223	.532772	.515390	.499857	.485799	.472927	.461165	.450568	.441131
.432705	.425083	.418139	.411883	.406368	.401584	.397423	.393763	.390557	.387841
.385861	.384001	.382782	.381931	.381439	.381352	.381711	.382497	.383651	.385128
.386942	.389149	.391787	.394838	.398254	.402010	.406139	.410710	.415763	.421280
.427219	.433573	.440407	.447809	.455823	.464425	.473579	.483313	.493733	.504962
.517045	.529953	.543667	.558276	.573986	.590901	.609134	.628631	.649433	.671752
.695907	.722138	.750508	.781023	.813884	.849567	.888649	.931504	.978266	1.029132
1.064746	1.140218	1.214687	1.290891	1.375309	1.468884	1.573647	1.692477	1.828131	1.982649
2.158194	2.358928	2.592170	2.867293	3.193257	3.577982	4.032137	4.575418	5.238282	6.051627
7.024127	8.118075	9.241292	10.267260	11.079040	11.614750	11.867210	11.963460	11.914980	11.768410
11.488930	11.006010	10.285600	9.276114	8.118747	6.920146	5.803378	4.847329	4.073328	3.459362
2.966803	2.562595	2.226223	1.946764	1.715608	1.523167	1.359972	1.219111	1.098912	.991460
.900723	.821954	.752448	.690468	.635315	.586814	.543641	.505300	.470613	.439102
.410877	.385236	.362403	.341647	.322583	.305103	.289244	.274941	.261957	.250011
.238958	.228810	.219607	.211287	.203687	.196862	.190173	.184263	.178952	.174175
.169824	.165832	.162207	.158991	.156181	.153721	.151542	.149624	.147995	.146682
.145870	.144912	.144373	.144063	.144010	.144229	.144699	.145390	.146293	.147432
.148633	.150498	.152409	.154556	.156954	.159635	.162618	.165899	.169472	.173352
.177575	.182178	.187174	.192563	.198365	.204629	.211415	.218761	.226685	.235212
.244410	.254381	.265217	.276971	.289688	.303465	.318472	.334909	.352934	.372657
.394231	.417947	.444225	.473501	.506122	.542432	.582981	.628689	.680742	.740328
.808551	.868789	.977327	1.083656	1.210052	1.360777	1.540038	1.753439	2.010139	2.323030
2.704009	3.153873	3.650642	4.143364	4.557676	4.815588	4.859037	4.672941	4.290567	3.782085
3.230524	2.706578	2.252865	1.882084	1.588130	1.348812	1.155379	.998023	.864758	.756942
.667942	.593357	.529795	.475157	.428186	.387820	.352894	.322286	.295181	.271127
.249846	.231019	.214242	.199136	.185462	.173113	.162006	.152006	.142929	.134628
.127027	.120105	.113825	.108110	.102869	.098040	.093603	.089558	.085879	.082519
.079429	.076564	.073986	.071634	.069510	.067561	.065822	.064228	.062804	.061549
.060448	.059479	.058630	.057905	.057309	.056840	.056484	.056231	.056076	.056025
.056083	.056247	.056508	.056858	.057300	.057842	.058487	.059232	.060073	.061008
.062039	.063177	.064426	.065785	.067251	.068827	.070521	.072343	.074298	.076388
.078816	.080985	.083511	.086206	.089080	.092138	.095386	.098838	.102513	.106435
.110619	.115077	.119822	.124881	.130291	.136091	.142311	.148973	.156113	.163767
.172072	.181043	.190759	.201275	.212681	.225122	.238781	.253830	.270405	.288664
.308863	.331498	.357019	.385850	.418216	.454354	.494904	.541120	.594435	.655183
.720963	.785615	.839780	.873300	.878643	.853780	.803068	.735864	.662259	.591730
.529163	.475820	.430522	.391392	.357008	.326870	.300064	.276860	.256554	.236584
.222506	.208052	.195065	.183394	.172856	.163267	.154491	.146449	.139088	.132349
.126153	.120429	.115125	.110216	.105678	.101481	.097585	.093958	.090579	.087439
.084525	.081818	.079298	.076948	.074759	.072727	.070843	.069097	.067477	.065973
.064503	.063303	.062130	.061054	.060069	.059171	.058360	.057632	.056986	.056414
.055914	.055485	.055128	.054835	.054612	.054452	.054354	.054317	.054342	.054429
.054576	.054781	.055045	.055367	.055750	.056193	.056694	.057255	.057876	.058557
.059302	.060111	.060984	.061921	.062924	.063997	.065141	.066358	.067648	.069015
.070461	.071990	.073605	.075308	.077103	.078992	.080981	.083074	.085277	.087594
.090028	.092587	.095277	.098106	.101080	.104206	.107491	.110945	.114580	.118407
.122435	.126675	.131138	.135839	.140800	.146036	.151558	.157379	.163513	.169987
.176825	.184031	.191573	.199398	.207454	.215716	.224160	.232876	.240953	.248405
.254223	.257559	.257800	.254786	.248088	.240869	.231647	.222014	.212488	.203302
.194502	.186076	.178027	.170388	.163194	.156450	.150135	.144208	.138635	.133393

.128485	.123831	.119470	.115358	.111478	.107815	.104357	.101092	.098007	.095089
.092328	.089717	.087245	.084908	.082696	.080602	.078621	.076746	.074974	.073298
.071714	.070217	.068804	.067470	.066214	.065031	.063919	.062873	.061893	.060976
.060117	.059318	.058574	.057886	.057248	.056663	.056127	.055639	.055198	.054803
.054452	.054145	.053881	.053659	.053478	.053337	.053236	.053174	.053152	.053168
.053222	.053314	.053443	.053609	.053812	.054053	.054330	.054645	.054998	.055384
.055810	.056273	.056773	.057311	.057887	.058502	.059155	.059848	.060579	.061350
.062162	.063014	.063908	.064843	.065820	.066839	.067902	.069008	.070157	.071352
.072590	.073874	.075203	.076576	.077995	.079458	.080966	.082518	.084114	.085751
.087428	.089144	.090896	.092681	.094494	.096331	.098184	.100047	.101909	.103758
.105577	.107341	.109027	.110808	.112680	.113356	.114484	.115342	.115941	.116215
.116129	.115878	.114884	.113793	.112458	.110934	.109261	.107472	.105591	.103644
.101854	.099845	.097637	.095844	.093677	.091742	.089843	.087986	.086173	.084407
.082689	.081021	.079401	.077832	.076313	.074843	.073423	.072051	.070726	.069450
.068219	.067034	.065894	.064798	.063748	.062735	.061765	.060835	.059944	.059092
.058277	.057499	.056757	.056050	.055377	.054738	.054131	.053557	.053014	.052501
.052019	.051568	.051141	.050745	.050377	.050036	.049721	.049433	.049171	.048934
.048722	.048535	.048371	.048231	.048115	.048022	.047952	.047905	.047880	.047877
.047895	.047935	.047996	.048079	.048182	.048306	.048450	.048614	.048799	.049003
.049227	.049470	.049732	.050013	.050313	.050632	.050968	.051322	.051694	.052083
.052489	.052912	.053350	.053804	.054273	.054758	.055252	.055762	.056284	.056817
.057361	.057914	.058475	.059043	.059617	.060194	.060773	.061353	.061931	.062504
.063072	.063630	.064176	.064706	.065218	.065708	.066172	.066605	.067003	.067361
.067675	.067942	.068158	.068323	.068438	.068506	.068528	.068508	.068448	.068348
.068209	.068029	.067804	.067535	.067217	.066853	.066444	.065993	.065504	.064983
.064433	.063861	.063269	.062662	.062042	.061414	.060778	.060139	.059498	.058858
.058220	.057585	.056957	.056335	.055720	.055115	.054519	.053934	.053360	.052798
.052249	.051712	.051189	.050680	.050184	.049703	.049236	.048784	.048346	.047923
.047515	.047121	.046743	.046379	.046031	.045696	.045377	.045072	.044782	.044506
.044245	.043998	.043765	.043546	.043341	.043150	.042972	.042808	.042657	.042519
.042394	.042282	.042183	.042096	.042022	.041960	.041910	.041872	.041846	.041831
.041827	.041835	.041854	.041883	.041922	.041972	.042032	.042102	.042181	.042270
.042368	.042474	.042588	.042711	.042841	.042979	.043124	.043275	.043433	.043596
.043764	.043937	.044114	.044294	.044478	.044664	.044852	.045041	.045230	.045419
.045807	.045792	.045975	.046153	.046327	.046498	.046657	.046811	.046958	.047092
.047217	.047331	.047433	.047521	.047595	.047655	.047701	.047732	.047749	.047751
.047742	.047721	.047692	.047657	.047618	.047579	.047540	.047501	.047463	.047423
.047379	.047328	.047268	.047196	.047111	.047013	.046901	.046774	.046634	.046481
.046315	.046137	.045948	.045749	.045540	.045323	.045099	.044868	.044632	.044391
.044148	.043898	.043648	.043396	.043144	.042891	.042638	.042387	.042136	.041888
.041842	.041399	.041160	.040924	.040692	.040464	.040241	.040022	.039809	.039601
.039398	.039202	.039010	.038825	.038646	.038473	.038307	.038146	.037992	.037845
.037704	.037569	.037441	.037320	.037205	.037096	.036994	.036898	.036809	.036726
.036649	.036579	.036514	.036456	.036403	.036357	.036316	.036281	.036252	.036227
.036208	.036194	.036185	.036181	.036181	.036186	.036195	.036208	.036225	.036246
.036269	.036296	.036326	.036359	.036393	.036430	.036469	.036509	.036550	.036593
.036635	.036678	.036721	.036763	.036805	.036845	.036883	.036919	.036954	.036985
.037013	.037038	.037060	.037077	.037090	.037098	.037101	.037100	.037093	.037081
.037064	.037042	.037015	.036983	.036948	.036909	.036867	.036823	.036778	.036733
.036689	.036648	.036610	.036576						

S(N) ANALYSIS - 80 EVENLY SPACED FREQUENCIES

FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)
.05000	.1	1.959998	10.718140
.10000	.2	.899816	3.825045
.15000	.3	.448664	1.869609

FREQUENCY(HZ)	FREQUENCY(P)	S(N)	VKS(N)
2.05000	4.1	.157763	.024198
2.10000	4.2	.099222	.023243
2.15000	4.3	.071105	.022349

.20000	.4	.383727	1.163075	2.20000	4.4	.057753	.021509
.25000	.5	.398256	.803638	2.25000	4.5	.053235	.020719
.30000	.6	.481313	.593771	2.30000	4.6	.055303	.019974
.35000	.7	.686593	.459578	2.35000	4.7	.063544	.019270
.40000	.8	1.244187	.368055	2.40000	4.8	.078574	.018606
.45000	.9	3.662810	.302552	2.45000	4.9	.100420	.017977
.50000	1.0	11.914950	.253886	2.50000	5.0	.116129	.017382
.55000	1.1	2.637568	.216634	2.55000	5.1	.096041	.016818
.60000	1.2	.656622	.187414	2.60000	5.2	.073986	.016282
.65000	1.3	.283361	.164025	2.65000	5.3	.059600	.015774
.70000	1.4	.173270	.144979	2.70000	5.4	.051478	.015290
.75000	1.5	.144362	.129239	2.75000	5.5	.048114	.014829
.80000	1.6	.159063	.116065	2.80000	5.6	.048579	.014391
.85000	1.7	.223432	.104916	2.85000	5.7	.052324	.013972
.90000	1.8	.403420	.095386	2.90000	5.8	.058701	.013573
.95000	1.9	1.107187	.087169	2.95000	5.9	.065603	.013192
1.00000	2.0	4.859002	.080029	3.00000	6.0	.068448	.012827
1.05000	2.1	.776876	.073780	3.05000	6.1	.063977	.012479
1.10000	2.2	.220760	.068278	3.10000	6.2	.055965	.012145
1.15000	2.3	.100897	.063403	3.15000	6.3	.049053	.011826
1.20000	2.4	.063926	.059062	3.20000	6.4	.044453	.011519
1.25000	2.5	.056076	.055178	3.25000	6.5	.042183	.011226
1.30000	2.6	.065498	.051687	3.30000	6.6	.041962	.010943
1.35000	2.7	.094059	.046537	3.35000	6.7	.043369	.010673
1.40000	2.8	.159110	.045683	3.40000	6.8	.045681	.010412
1.45000	2.9	.336358	.043088	3.45000	6.9	.047537	.010162
1.50000	3.0	.878638	.040721	3.50000	7.0	.047540	.009921
1.55000	3.1	.281253	.038556	3.55000	7.1	.046512	.009689
1.60000	3.2	.128577	.036569	3.60000	7.2	.043748	.009466
1.65000	3.3	.078340	.034741	3.65000	7.3	.040600	.009251
1.70000	3.4	.059002	.033055	3.70000	7.4	.038115	.009044
1.75000	3.5	.054341	.031498	3.75000	7.5	.036649	.008844
1.80000	3.6	.059943	.030052	3.80000	7.6	.036181	.008651
1.85000	3.7	.076373	.028710	3.85000	7.7	.036453	.008464
1.90000	3.8	.108861	.027462	3.90000	7.8	.036968	.008284
1.95000	3.9	.171326	.026299	3.95000	7.9	.037036	.008110
2.00000	4.0	.257798	.025212	4.00000	8.0	.036546	.007942

FREQUENCIES

.002500	.005000	.007500	.010000	.012500	.015000	.017500	.020000	.022500	.025000
.027500	.030000	.032500	.035000	.037500	.040000	.042500	.045000	.047500	.050000

S(N)

7.58	7.53	7.44	7.29	7.08	6.79	6.43	6.01	5.55	5.08
4.58	4.12	3.71	3.34	3.01	2.74	2.50	2.30	2.12	1.96

SUMS OF S(N) FOR THE TWO SERIES 38.94 97.15
VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.0899 (M/S)**2
LENGTH SCALE FROM INTEGRATION OF ACF IS 8.3 M
VARIANCES FOR FIRST HALF-P AND FOR 8P FROM 80-MEMBER SPECTRUM
S(N)C, - (M/S)**2

$\sigma(N)/\sigma_1(N)$	$\sigma(N)/\sigma_2(N)$	$\sigma(N)/\sigma_3(N)$	$\sigma(N)/\sigma_4(N)$	$\sigma(N)/\sigma_5(N)$	$\sigma(N)/\sigma_6(N)$	$\sigma(N)/\sigma_7(N)$
.3393	1.0942	.3985	.1068	.0557	.0372	.0275

RMS	.5825	1.0481	.6313	.3267	.2359	.1928	.1658
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SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA

VARIANCES FOR FIRST HALF-P AND FOR 6P FROM

SPECTRUM OF SIMULATED DATA, S(N)R
 .3582 1.1089 .3634 .1023 .0554 .0373 .0276
 SPECTRAL ESTIMATES FROM SIMULATED DATA
 FIRST NUMBER IS SERIES MEAN

.0000	7.5606	7.4268	7.1538	6.7073	6.0931	5.3658	4.6103	3.9089	3.3137
2.8371	2.4622	2.1619	1.9138	1.7054	1.5308	1.3857	1.2643	1.1605	1.0701
.9908	.9219	.8623	.8103	.7641	.7226	.6855	.6525	.6234	.5974
.5737	.5522	.5328	.5154	.4999	.4858	.4729	.4612	.4506	.4411
.4327	.4251	.4181	.4119	.4064	.4016	.3974	.3938	.3906	.3878
.3857	.3840	.3828	.3819	.3814	.3814	.3817	.3825	.3837	.3851
.3869	.3891	.3918	.3948	.3983	.4020	.4061	.4107	.4158	.4213
.4272	.4336	.4404	.4478	.4558	.4644	.4736	.4833	.4937	.5050
.5170	.5300	.5437	.5583	.5740	.5909	.6091	.6286	.6494	.6718
.6959	.7221	.7505	.7810	.8139	.8496	.8886	.9315	.9783	1.0291
1.0847	1.1482	1.2147	1.2909	1.3753	1.4689	1.5736	1.6925	1.8281	1.9826
2.1582	2.3589	2.5922	2.8673	3.1933	3.5780	4.0321	4.5754	5.2383	6.0516
7.0241	8.1181	9.2413	10.2673	11.0790	11.6147	11.8872	11.9635	11.9150	11.7884
11.4889	11.0060	10.2857	9.2761	8.1187	6.9201	5.8034	4.8473	4.0733	3.4594
2.9689	2.5626	2.2262	1.9488	1.7156	1.5232	1.3600	1.2191	1.0989	.9915
.9007	.8220	.7524	.6905	.6353	.5866	.5436	.5053	.4706	.4391
.4107	.3852	.3624	.3418	.3226	.3051	.2892	.2749	.2620	.2500
.2390	.2288	.2196	.2113	.2037	.1967	.1902	.1843	.1790	.1742
.1698	.1658	.1622	.1590	.1562	.1537	.1515	.1496	.1480	.1467
.1457	.1449	.1444	.1441	.1440	.1442	.1447	.1454	.1463	.1474
.1488	.1505	.1524	.1546	.1570	.1596	.1626	.1659	.1695	.1734
.1776	.1822	.1872	.1926	.1984	.2046	.2114	.2188	.2267	.2352
.2444	.2544	.2652	.2770	.2897	.3035	.3185	.3349	.3529	.3727
.3942	.4179	.4442	.4735	.5061	.5424	.5830	.6287	.6807	.7403
.8086	.8888	.9773	1.0837	1.2101	1.3688	1.5400	1.7534	2.0101	2.3230
2.7040	3.1539	3.6506	4.1434	4.6579	4.8156	4.8590	4.6729	4.2906	3.7821
3.2305									

VARIANCE OF S(N)R FROM SIMULATED DATA 2.0839
 SMOM(1), SMOM(2) .0000 2.0839
 SKEWNESS AND KURTOSIS -.1400 3.0000
 HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED
 24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE
 BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ), NS(N), HARMONIC COUNT PER BAND [NS(N):ORIG	SIM	VK	VKA]
3.56500 4.00000 3.17731 211 814 1024 .14774	.14774	.02819	.03424
2.83178 3.17731 2.52383 168 647 814 .17329	.17329	.03283	.03988
2.24937 2.52383 2.00475 134 514 647 .20761	.20761	.03825	.04646
1.78673 2.00475 1.59243 106 409 514 .18236	.18236	.04453	.05409
1.41925 1.59243 1.26491 85 325 409 .38386	.38386	.05183	.06295
1.12735 1.26491 1.00475 68 258 325 .63442	.63442	.06044	.07341
.89549 1.00475 .79810 54 205 258 .96112	.96112	.07048	.08560
.71131 .79810 .63396 43 163 205 .13583	.13583	.08209	.09989
.56502 .63396 .50357 34 130 163 1.86356	1.86356	.09530	.11573
.44881 .50357 .40000 28 103 130 2.46765	2.46765	.11096	.13471
.35650 .40000 .31773 22 82 103 .27940	.27940	.12938	.15702
.28318 .31773 .25238 17 66 82 .12873	.12873	.14887	.18059
.22494 .25238 .20047 15 52 66 .08709	.08709	.17270	.20933
.17867 .20047 .15924 11 42 52 .07151	.07151	.19971	.24178
.14193 .15924 .12649 10 33 42 .06695	.06695	.23125	.27943
.11274 .12649 .10048 7 27 33 .06792	.06792	.26461	.31883
.08955 .10048 .07981 7 21 27 .07365	.07365	.30476	.36548

.07113	.07981	.06340	5	17	21	.08353	.08353	.35284	.42008
.05650	.06340	.05036	4	14	17	.09232	.09232	.38824	.45781
.04488	.05036	.04000	4	11	14	.10519	.10519	.43484	.50483
.03585	.04000	.03177	3	9	11	.11954	.11954	.48398	.54940
.02832	.03177	.02524	3	7	9	.13106	.13106	.53419	.58613
.02249	.02524	.02005	2	6	7	.12888	.12888	.55789	.58896
.01787	.02005	.01592	2	5	6	.11435	.11435	.54572	.55253

UNBANDIED NSN SPECTRA

.003906	.029534	.029534	.236679	.180423
.007813	.058022	.058022	.408456	.344820
.011719	.083834	.083834	.495561	.458671

ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT

A, B, AMP, ANGLE IN DEGREES - .2961 - .0736 .3051 -168.0503

PHASE ANGLE FOR 1P IN SIMULATED DATA -168.1 DEGREES

OFFSET ANGLE BETWEEN MEAN WIND AND TURBULENCE AT 1P (DELAY) .0 DEGREES

OFFSET, IFFSET, -7.4 11

ONE CYCLE OF MEAN WIND EFFECT - M/S

44.17 43.41 44.17 46.34 49.58 53.41 57.23 60.48 62.65 63.41 62.65 60.48 57.23 53.41 49.58 46.34

NUMBER OF COMPLETE MEAN WIND CYCLES IN SIMULATION 128

VARIANCES FOR FIRST HALF-P AND FOR 8P FROM

SPECTRUM OF SIMULATED DATA, S(N)R

.3582	54.1280	.3634	.1023	.0554	.0373	.0276
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SPECTRAL ESTIMATES FROM SIMULATED DATA

FIRST NUMBER IS SERIES MEAN

53.4071	7.5606	7.4268	7.1538	6.7073	6.0931	5.3658	4.6103	3.9089	3.3137
2.8371	2.4622	2.1619	1.9138	1.7054	1.5308	1.3857	1.2643	1.1605	1.0700
.9908	.9219	.8623	.8103	.7641	.7226	.6855	.6525	.6234	.5974
.5737	.5522	.5328	.5154	.4999	.4858	.4729	.4612	.4506	.4411
.4327	.4251	.4181	.4119	.4064	.4016	.3974	.3938	.3906	.3878
.3857	.3840	.3828	.3819	.3814	.3814	.3817	.3825	.3837	.3851
.3869	.3891	.3918	.3948	.3983	.4020	.4061	.4107	.4158	.4213
.4272	.4336	.4404	.4478	.4558	.4644	.4736	.4833	.4937	.5050
.5171	.5300	.5437	.5583	.5740	.5909	.6091	.6286	.6494	.6718
.6959	.7221	.7505	.7810	.8139	.8496	.8888	.9315	.9783	1.0291
1.0847	1.1462	1.2147	1.2909	1.3753	1.4689	1.5736	1.6925	1.8281	1.9826
2.1582	2.3589	2.5922	2.8673	3.1933	3.5700	4.0321	4.5754	5.2303	6.0516
7.0241	8.1181	9.2413	10.2872	11.0790	11.6147	11.8872	11.9635	13584.2900	11.7684
11.4889	11.0060	10.2657	9.2761	8.1187	6.9201	5.8034	4.8473	4.0733	3.4594
2.9689	2.5626	2.2262	1.9488	1.7156	1.5232	1.3600	1.2191	1.0969	.9915
.9007	.8220	.7524	.6905	.6353	.5866	.5436	.5053	.4706	.4391
.4107	.3852	.3624	.3416	.3226	.3051	.2892	.2749	.2620	.2500
.2390	.2288	.2196	.2113	.2037	.1967	.1902	.1843	.1790	.1742
.1698	.1658	.1622	.1590	.1562	.1537	.1515	.1496	.1480	.1467
.1457	.1449	.1444	.1441	.1440	.1442	.1447	.1454	.1463	.1474
.1488	.1505	.1524	.1546	.1570	.1596	.1626	.1659	.1695	.1734
.1776	.1822	.1872	.1926	.1984	.2046	.2114	.2188	.2267	.2352
.2444	.2544	.2652	.2770	.2897	.3035	.3185	.3349	.3529	.3727
.3942	.4179	.4442	.4735	.5061	.5424	.5830	.6287	.6807	.7403
.8086	.8868	.9773	1.0837	1.2101	1.3608	1.5400	1.7534	2.0101	2.3230
2.7040	3.1539	3.6506	4.1434	4.6579	4.8156	4.8590	4.6729	4.2906	3.7821
3.2305									

VARIANCE OF S(N)R FROM SIMULATED DATA 55.1011

SMOM(1), SMOM(2) 53.4071 55.1011

SKEWNESS AND KURTOSIS .0276 1.5932

HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED

24 LOGARITHMICALLY SPACED BANDS AT						10. PER SPECTRAL DECADE			
BANDED NSN SPECTRA									
BAND CENTER, HI, LOW (HZ),	NS(N),	HARMONIC	COUNT	PER BAND	[NS(N):ORIG	SIM	VK	VKA]	
3.56500	4.00000	3.17731	211	814	1024	.14774	.02819	.03424	
2.83178	3.17731	2.52383	188	847	814	.17329	.03283	.03988	
2.24937	2.52383	2.00475	134	514	847	.20761	.03625	.04848	
1.78673	2.00475	1.59243	106	409	514	.18238	.04453	.05409	
1.41925	1.59243	1.26491	85	325	409	.38388	.05183	.06295	
1.12735	1.26491	1.00475	68	258	325	.63442	.06044	.07341	
.89549	1.00475	.79810	54	205	258	.98112	.07048	.08560	
.71131	.79810	.63398	43	183	205	.13583	.08209	.09989	
.56502	.63398	.50357	34	130	183	1.86358	.09530	.11573	
.44881	.50357	.40000	28	103	130	2.46785	.11098	.13471	
.35650	.40000	.31773	22	82	103	.27940	.12938	.15702	
.28318	.31773	.25238	17	68	82	.12873	.14887	.18059	
.22494	.25238	.20047	15	52	68	.08709	.17270	.20933	
.17867	.20047	.15924	11	42	52	.07151	.19971	.24178	
.14193	.15924	.12649	10	33	42	.06895	.23125	.27943	
.11274	.12649	.10048	7	27	33	.06792	.26481	.31883	
.08955	.10048	.07981	7	21	27	.07385	.30478	.36548	
.07113	.07981	.06340	5	17	21	.08353	.35284	.42008	
.05650	.06340	.05036	4	14	17	.09232	.38824	.45781	
.04488	.05036	.04000	4	11	14	.10519	.43484	.50483	
.03565	.04000	.03177	3	9	11	.11954	.48398	.54940	
.02832	.03177	.02524	3	7	9	.13106	.53419	.58613	
.02249	.02524	.02005	2	6	7	.12888	.55789	.58898	
.01787	.02005	.01592	2	5	6	.11435	.54572	.55253	
UNBANDED NSN SPECTRA									
.003908	.029534	.029534	.238679	.180423					
.007813	.058022	.058022	.408458	.344820					
.011719	.083834	.083834	.495581	.458671					

F.3 SERIES.DAT TANGENTIAL

2048	1.051138	-2.326383E-01	-6.827620E-01	1.196113
6.817674E-01	-2.100778E-01	1.937002E-01	1.132430	
2.354859	4.739547E-01	5.467072E-02	9.370092E-01	
6.225157E-01	-2.333065E-01	-6.431525E-01	5.875106E-01	
1.136702	1.642806	7.034974E-01	2.033785	
2.492098	2.689084	1.146859	1.891084	
7.397202E-01	7.363316E-01	-3.128805E-01	7.742317E-01	
1.201247	6.857287E-01	-7.601023E-03	4.086212E-01	
1.520632	1.384387	4.330438E-01	4.439326E-01	
1.076572	3.430647E-02	-2.865091E-01	9.879246E-03	
9.401818E-01	1.445454E-02	4.799731E-01	1.784453	
2.609351	1.002192	-6.534668E-01	1.786357E-02	
1.010705	5.689090E-01	7.620940E-02	-8.677259E-01	
-2.185825	-1.924092	-4.431619E-02	5.933250E-01	
8.323709E-01	1.853287E-01	6.271771E-01	7.162939E-01	
1.054134	8.051711E-01	-4.314704E-01	7.225925E-01	
4.152327E-01	-3.976426E-01	3.471197E-01	-3.137631E-01	
-1.781434	-2.309626	-2.362781	-1.130293	
-2.881706E-01	-2.303873E-01	1.102570	1.034222	
-6.454134E-02	7.357687E-02	-3.324032E-03	-7.072187E-01	
-1.441153	-1.470382	-3.369921E-01	-7.592404E-01	
-2.447961	-2.416427	-1.204454	-7.569432E-01	
2.308170E-01	1.559501	2.198879	1.079160	
1.434877	1.701380	2.675078E-01	-3.681183E-01	
-8.924331E-01	2.213722E-01	4.724997E-01	-1.493910	
-1.888890	-3.895609	-3.200524	-1.641135	
4.756033E-01	5.885023E-01	-1.518351E-01	-3.158931E-01	
7.351530E-01	1.183750	7.097195E-01	-8.610476E-01	
-2.268027	-1.397331	-8.290087E-01	-1.105589	
-1.530435	-2.486446	-2.628918	-1.478112	
-9.767783E-01	-3.154507E-01	5.836936E-01	1.158070	
9.444835E-01	4.709713E-01	8.527434E-02	-1.040904E-01	
-1.383080	-5.703658E-01	3.168085E-01	-8.085752E-01	
-5.768582E-01	-9.239954E-01	-1.622972	1.571420E-01	
-5.097674E-01	4.313964E-01	6.907029E-01	1.380739	
5.717274E-01	-6.807423E-01	3.311783E-02	-1.628126	
-1.749754	5.079399E-01	1.733885	1.653426E-01	
1.352924	1.300147	2.525209E-01	6.884555E-01	
8.025355E-01	-4.206859E-01	-4.165338E-01	-7.769002E-01	
-4.879788E-01	-8.637288E-01	-1.035412	-7.419152E-01	
-1.028981	-7.661941E-01	-1.944946E-01	6.048651E-01	
5.467252E-01	1.006586	1.932082	1.452407	
1.159467	2.461531E-01	-1.566860	-2.288621	
-2.087901	-2.557558	-1.410833	1.759651E-01	
3.383798E-01	4.610217E-01	-2.652228E-01	-4.315395E-01	
5.918223E-01	6.727916E-01	9.906483E-01	1.019785	
7.897547E-01	-1.257249	-1.637105	-7.409930E-01	
-8.869100E-01	-6.034482E-01	9.603941E-02	1.424238	
1.301735	6.229641E-01	6.825126E-01	-2.032863E-01	

6.546220E-01	1.457404	2.005756	9.622344E-01
-8.537071E-01	-2.232029	-2.996264	-3.212029
-2.306373	-1.290151	-8.946613E-01	1.079619
2.923611E-01	4.175210E-01	1.037795	-8.201417E-01
-8.040766E-01	-3.728825E-01	1.687684	1.561277
8.796937E-01	-1.425908	-2.006968	-2.582301
-6.880482E-01	1.289505	9.932078E-01	3.023097
2.705293	2.720352	1.952042	1.592752E-01
-2.875695E-01	-5.879448E-01	4.695632E-01	4.316583E-01
-1.236680	-2.278653	-2.672312	-4.122166
-3.509962	-2.475646	-8.864627E-02	1.775221
2.090144	1.853384	1.465247	9.437862E-02
7.364863E-01	9.731389E-01	1.148533	1.410037
2.194453E-01	-3.430899E-01	-1.826963	-2.026196
-1.465134	-1.834794	5.588628E-01	1.548123
1.959489	1.867034	1.292582	1.471884E-01
-4.454323E-01	1.735535E-01	5.720872E-02	-6.078501E-02
-8.752889E-01	-1.950006	-2.377245	-1.073992
-2.158545E-01	2.561966E-01	-5.231377E-02	1.264736
1.501421E-01	7.117106E-01	-2.068771E-01	-1.160875
-7.209004E-02	1.222843	-3.919815E-01	-9.662607E-02
1.340933E-01	-2.214267	-1.388936	-5.307562E-01
7.615790E-02	4.983848E-01	1.093145	9.623171E-01
3.123285E-01	-8.539450E-01	-1.195878	-6.074457E-01
3.774565E-01	1.308716	1.195940	-4.697455E-01
1.203094	1.063544E-01	-1.254069	-5.426571E-01
-1.950085E-01	-2.362304E-01	2.682337E-01	-3.555407E-01
-3.997802E-01	-1.733692	-2.682276	-4.720524E-02
1.474990	1.778407	1.639337	1.209486
1.742048	1.194565	1.192372	-2.382092E-02
-7.632515E-01	-1.160933	-1.348235	-9.923161E-01
-8.931289E-01	-2.376684	-1.249843	-3.798803E-01
1.277937	1.755772	1.783175	1.926566
1.354441	5.180949E-01	7.272233E-01	6.253822E-01
7.416810E-01	-5.209801E-01	-8.624381E-01	-1.197177
-1.048522	-1.898632	-2.155873	-1.662618
-7.545106E-01	2.317254E-02	-3.282516E-01	-6.751956E-01
-1.451326	-1.578448	-5.320287E-01	3.917460E-01
1.183120	4.047588E-01	7.237583E-02	-3.891190E-01
-4.146470E-01	1.682306E-01	-2.303596	-7.175016E-01
-1.423134	3.512870E-01	-2.004132E-01	-8.431817E-01
-1.009657	-8.343244E-01	6.253631E-01	8.938084E-01
-4.232703E-01	-8.699865E-01	-1.008901	-1.635908
-9.750667E-01	-1.412718E-01	-1.039998	-1.370474
-1.888868	-1.369395	-8.801335E-02	-7.628683E-01
-1.516093	-1.781234E-01	2.297914	2.989880
1.085660	-3.865188E-01	5.373337E-01	-3.359957E-01
-6.996506E-01	2.551720E-01	-2.301319E-01	-1.833097
-1.985529	-2.467761	-9.585816E-01	-3.599594E-01
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1.559687E-02	-7.908731E-01	-1.053522	-1.345542
-9.348844E-01	-1.434887	-2.446161	-1.782630
-1.645678	-7.364579E-01	-6.070750E-01	-1.172868E-01
5.230330E-01	1.362692	1.927774	2.264285
1.721527	9.480217E-01	-1.214676	-6.071310E-01

-4.268135E-01	-1.680018	-1.472386	-2.130280
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3.468389E-01	1.599462	1.868987	1.534052
1.304360	9.873635E-01	1.060765	2.054405
7.644687E-01	-8.576759E-01	-1.173286	-9.352695E-01
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-8.002233E-01	-1.232540E-01	-7.194420E-01	-9.521040E-01
-2.175202E-01	-4.587740E-01	7.015000E-01	9.982315E-01
1.485459	1.439718	3.629877E-01	-9.283584E-02
-1.338428	-1.333154	-5.396338E-01	-9.339167E-01
-4.375479E-01	1.713872E-03	-9.749063E-01	3.280649E-01
3.345000E-01	-6.777468E-01	-1.162810	1.040668
9.354713E-01	8.107034E-01	-6.464444E-01	-1.605655
-1.547277	-5.607926E-01	-6.594214E-01	-2.170260E-01
-4.197385E-01	1.017819	1.466376	2.478656
2.428685	2.428103	7.224633E-01	7.171675E-01
1.158971	4.831008E-01	-4.012166E-01	-1.121069
-1.873808	-7.637304E-01	3.222170E-01	3.159811E-01
1.550018	2.764403	1.350381	2.158101
2.702609	2.623972	6.023763E-01	1.331975
-2.454472E-01	-1.186809	-8.700249E-01	-5.611809E-01
2.924930E-01	8.703082E-01	1.203818	1.701123
2.261741	2.542218	2.154277	3.784863E-01
7.695215E-01	1.026426	8.342954E-01	2.252037E-02
-1.211186	-2.436257	-3.019981	-3.006248
-1.537669	1.237930	2.132734	1.101885
6.787815E-01	1.072947	-1.715858E-01	-2.212066E-01
-8.136392E-01	-3.230311E-01	1.084990	9.483936E-01
5.149066E-01	-3.469246E-01	-1.782456	-6.708658E-01
2.706046E-01	1.156131	4.829216E-01	1.732361
1.101030	1.589469	2.309091E-01	-1.574277E-01
-2.662859E-01	-2.465699E-01	-1.355061	5.372552E-01
1.069101	-1.022315	-1.782490	-7.093160E-01
-2.594931E-01	1.201186E-01	9.375568E-01	1.126494
1.382841	2.158128	2.558307	1.462526
2.611743E-01	1.481081E-01	-5.805624E-02	2.355934
2.832802	3.418933E-01	6.639571E-01	6.430317E-01
-9.984127E-02	-3.546037E-01	2.478461E-01	7.352951E-01
2.515226E-01	1.592105	1.636616	1.671133
6.296333E-01	-3.916948E-01	4.003277E-01	4.323168E-01
1.210413	-6.386638E-05	4.382498E-01	-5.135658E-01
-1.466824	-1.486729	-7.170471E-01	-9.000390E-01
-3.053753E-02	7.342321E-01	5.904837E-01	1.140459
1.298016	2.139348E-02	-8.797094E-01	6.677673E-01
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-1.906132	-2.535987	-9.655727E-01	-1.076276
-3.612632E-02	1.028317	4.657812E-01	1.606686
1.241458	-4.740530E-01	1.181700E-01	5.969836E-01
2.297142E-01	-6.182736E-01	-2.024798	-2.338697
-3.499693	-2.611899	-2.106461	-1.008544
8.870816E-02	1.224998	2.340368	3.401139
2.151045	8.799014E-01	-5.385606E-01	-1.155906
-1.051515	-9.974436E-01	-8.319000E-01	-7.372625E-01
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50.262010	53.197000	57.427610	61.610500	
65.000730	63.881030	62.700550	61.416150	
57.656430	53.173770	48.937090	46.923520	
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52.072340	56.096160	58.380770	62.369230	
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42.785200	42.836710	44.485170	45.527440	
49.003590	52.483080	55.610940	60.635290	
62.136110	63.838470	63.338580	61.858880	
57.805640	52.726330	49.613360	44.707890	
42.418530	43.915020	45.902170	46.501360	
50.933170	54.707230	57.486430	61.166600	
63.448410	62.986390	62.229340	59.701240	
56.745930	52.543350	48.544830	45.594090	
43.139300	42.640880	43.973790	46.940880	
50.126970	54.413660	59.166000	61.930550	
63.805340	63.653230	61.079010	58.191520	
55.146010	50.849520	48.169610	46.511970	
44.506660	43.888100	43.903060	45.904480	
50.172070	54.079670	58.224560	61.497930	
63.435630	62.149830	61.008770	59.737150	
56.347000	52.803630	49.676280	47.760250	
45.470020	44.030040	44.850800	46.132730	
50.234860	54.864480	59.239670	61.440380	
61.792170	61.174450	59.649610	57.268120	
54.927540	52.116930	48.685580	47.415630	
44.460640	43.824600	45.208080	45.515870	
48.776170	53.034190	58.921600	62.039420	
63.525570	61.981170	60.638900	57.895840	

56.545860	54.696580	50.573450	49.359110
46.873570	46.127430	46.120320	46.495290
49.292670	52.819130	57.703480	60.909810
61.409190	61.128430	59.973560	56.355980
53.723950	50.931430	49.491390	48.111230
46.256430	45.260460	45.633530	46.430390
50.316730	54.380220	58.382450	61.888180
62.865320	63.003990	60.818910	58.451950
55.768780	51.572280	50.139110	47.884130
46.127770	45.274110	45.460870	46.483180
49.134810	53.580630	57.291120	60.409360
61.770580	61.457070	60.268630	59.404150
57.018050	53.663270	49.527930	47.600750
44.318420	44.118790	43.961400	45.175140
49.506150	54.629920	56.841930	60.381520
62.779970	61.192810	61.256940	59.947390
57.310070	53.905460	50.673390	47.298330
44.480610	42.553130	42.972400	45.728570
49.957700	54.713790	58.429860	60.008400
63.646970	63.513430	61.391800	59.935490
57.038900	53.170850	49.848480	45.980470
43.768500	41.673390	41.486000	46.288810
51.055230	55.185490	58.873250	61.687630
64.387920	64.601650	63.838250	60.454320
56.470660	52.246140	48.232010	45.343690
43.275150	41.030400	42.918440	45.956150
50.856180	55.162850	59.017090	62.404710
64.000310	63.925170	63.373100	61.103530
57.975590	52.886100	48.717800	45.136830
43.119760	41.510440	42.012610	44.673400
46.825730	53.430250	56.905660	59.802950
61.194550	61.830630	62.113850	60.869890

F.4 SUMMARY.BRF NORMAL

VAWT NORMAL SIMULATION
 SERIAL NUMBER VTNML
 RADIUS OF ROTATION 17.0 M
 RATE OF ROTATION .5000 HZ
 HUB HEIGHT 29.0 M
 SURFACE ROUGHNESS LENGTH .0500 M
 MEAN WIND SPEED 10.00 M/S
 TURBULENCE RMS VALUES
 U-COMPONENT 1.509 M/S
 V-COMPONENT 1.509 M/S
 TURBULENCE VARIANCES
 U-COMPONENT 2.276 (M/S)**2
 V-COMPONENT 2.276 (M/S)**2
 FRICTION VELOCITY .029 M/S
 TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 121.8 M
 LATERAL 48.7 M
 NUMBER DATA TO BE SIMULATED 2048
 DISCRETIZATION INTERVAL .1250 SEC
 ALIAS FACTOR 4
 ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
 NANGLE WAS READ IN - DT WAS CALCULATED
 ALFA, BETA .3489 .0261
 LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
 NUMBER OF HARMONICS IN SPECTRA 1024
 THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
 SPECTRUM AND REDUCED VERSION.
 FUNDAMENTAL FREQUENCY IS .003906 HZ

 MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
 VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.1500 (M/S)**2
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM
 S(N)C, - (M/S)**2
 .3032 1.1178 .3692 .1469 .0797 .0524 .0383
 RMS
 .5500 1.0573 .0077 .3033 .2823 .2289 .1957
 SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA
 .7004 .1058 .0301 .0152 .0094 .0065 .0048
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .3063 1.0184 .3409 .1394 .0781 .0521 .0382
 VARIANCE OF S(N)R FROM SIMULATED DATA 2.0156
 SKEWNESS AND KURTOSIS -.1803 3.0044
 ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT
 VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .3063 51.5416 .3409 .1394 .0781 .0521 .0382
 VARIANCE OF S(N)R FROM SIMULATED DATA 52.5389
 SKEWNESS AND KURTOSIS -.0574 1.6047

F.5 SUMMARY.DAT NORMAL

VAWT NORMAL SIMULATION
 SERIAL NUMBER VTNNL
 RADIUS OF ROTATION 17.0 M
 RATE OF ROTATION .5000 HZ
 HUB HEIGHT 29.0 M
 SURFACE ROUGHNESS LENGTH .0500 M
 MEAN WIND SPEED 10.00 M/S
 TURBULENCE RMS VALUES
 U-COMPONENT 1.509 M/S
 V-COMPONENT 1.509 M/S
 TURBULENCE VARIANCES
 U-COMPONENT 2.276 (M/S)**2
 V-COMPONENT 2.276 (M/S)**2
 FRICTION VELOCITY .029 M/S
 TURBULENCE INTEGRAL LENGTH SCALES
 LONGITUDINAL 121.8 M
 LATERAL 48.7 M
 NUMBER DATA TO BE SIMULATED 2048
 DISCRETIZATION INTERVAL .1250 SEC
 ALIAS FACTOR 4
 ANGULAR DISCRETIZATION INTERVAL 22.5 DEGREES
 ANGLE WAS READ IN - DT WAS CALCULATED
 ALFA, BETA .3469 .0261
 LIMIT ON MEMBERS OF AUTOCORRELATION FUNCTION 4096
 NUMBER OF HARMONICS IN SPECTRA 1024
 THIS IS ALSO A COMPARISON BETWEEN NUMBER OF HARMONICS IN ORIGINAL
 SPECTRUM AND REDUCED VERSION.
 FUNDAMENTAL FREQUENCY IS .003906 HZ

 MAX FINAL VALUE OF CORRELATION ACCEPTABLE WITHOUT WINDOWING .00100
 DIFFERENT FORMS OF VARIABLES:
 - ORIGINAL
 -A - INCLUDING EXTENSIONS ASSOCIATED WITH ALIAS REMOVAL
 -ND - DIMENSIONLESS VARIABLE
 -AND - BOTH OF THE ABOVE
 DISCRETIZATION INTERVAL - DT
 .125 SEC
 -A .031 SEC
 -ND .198
 -AND .049
 NUMBER OF SIMULATED DATA - MMT
 2048
 -A 8192
 FUNDAMENTAL FREQUENCY - EN1
 .00391 HZ
 -ND .00249
 NYQUIST FREQUENCY - EN2
 4.00000 HZ
 -A 16.00000 HZ

ND 2.54848
 -AND 10.18592
 NUMBER OF SAMPLING POSITIONS IN CIRCLE - NANGLE

16
 -A 64
 ANGLEA 3.1416
 COSA, SINA -1.000 .000

DIRECTION COSINES FOR MOVING POINT
 SHANNING WINDOW USED - LAST R BEFORE USE .0002
 AUTOCORRELATION FUNCTION 1048 STEPS 32.75 SECONDS
 AFTER FIRST VALUE SKIP INTERVAL IS 2

.0861	.7122	.5760	.4498	.3342	.2310	.1409	.0643	.0005	-.0512	-.0923	-.1240	-.1478	-.1648	-.1761
-.1823	-.1841	-.1815	-.1748	-.1628	-.1456	-.1219	-.0905	-.0498	.0018	.0655	.1435	.2387	.3455	.4680
.5953	.6941	.7022	.6208	.5071	.3928	.2877	.1960	.1183	.0542	.0027	-.0379	-.0691	-.0925	-.1097
-.1217	-.1298	-.1341	-.1355	-.1340	-.1295	-.1218	-.1095	-.0923	-.0688	-.0374	.0037	.0561	.1214	.2004
.2918	.3902	.4818	.5425	.5488	.5004	.4194	.3283	.2410	.1638	.0989	.0462	.0048	-.0274	-.0514
-.0692	-.0819	-.0907	-.0965	-.0998	-.1009	-.1000	-.0968	-.0912	-.0824	-.0696	-.0518	-.0271	.0055	.0478
.1010	.1651	.2381	.3137	.3803	.4221	.4288	.3941	.3354	.2857	.1965	.1342	.0817	.0393	.0062
-.0190	-.0378	-.0512	-.0608	-.0675	-.0718	-.0743	-.0751	-.0745	-.0722	-.0680	-.0614	-.0517	-.0379	-.0188
.0069	.0404	.0825	.1329	.1893	.2463	.2949	.3247	.3281	.3049	.2621	.2097	.1564	.1078	.0685
.0331	.0072	-.0124	-.0268	-.0372	-.0448	-.0497	-.0530	-.0549	-.0558	-.0551	-.0534	-.0501	-.0451	-.0378
-.0289	-.0122	.0077	.0338	.0661	.1048	.1472	.1893	.2245	.2458	.2482	.2316	.2005	.1618	.1217
.0848	.0532	.0278	.0077	-.0073	-.0184	-.0285	-.0321	-.0361	-.0388	-.0401	-.0408	-.0402	-.0388	-.0363
-.0324	-.0286	-.0184	-.0072	.0079	.0275	.0519	.0806	.1118	.1423	.1675	.1824	.1841	.1722	.1500
.1219	.0928	.0652	.0417	.0225	.0078	-.0037	-.0121	-.0182	-.0228	-.0257	-.0278	-.0288	-.0292	-.0288
-.0277	-.0257	-.0227	-.0182	-.0120	-.0038	.0078	.0220	.0398	.0606	.0829	.1044	.1220	.1323	.1333
.1250	.1094	.0895	.0686	.0489	.0319	.0180	.0070	-.0013	-.0078	-.0121	-.0155	-.0178	-.0193	-.0202
-.0205	-.0202	-.0193	-.0177	-.0154	-.0120	-.0074	-.0012	.0069	.0172	.0298	.0443	.0598	.0745	.0864
.0933	.0939	.0882	.0775	.0638	.0494	.0357	.0238	.0139	.0062	.0002	-.0044	-.0077	-.0102	-.0120
-.0131	-.0138	-.0140	-.0137	-.0130	-.0118	-.0100	-.0075	-.0042	.0002	.0059	.0130	.0218	.0313	.0417
.0514	.0592	.0638	.0639	.0601	.0530	.0439	.0343	.0251	.0171	.0104	.0051	.0009	-.0023	-.0047
-.0065	-.0077	-.0086	-.0091	-.0092	-.0090	-.0085	-.0075	-.0062	-.0045	-.0021	.0009	.0047	.0094	.0150
.0213	.0279	.0340	.0389	.0416	.0417	.0392	.0347	.0290	.0228	.0170	.0118	.0074	.0039	.0012
-.0010	-.0028	-.0039	-.0048	-.0054	-.0057	-.0058	-.0058	-.0052	-.0046	-.0037	-.0024	-.0009	.0011	.0035
.0065	.0099	.0137	.0177	.0213	.0242	.0257	.0257	.0242	.0215	.0180	.0143	.0108	.0078	.0050
.0028	.0011	-.0003	-.0013	-.0022	-.0028	-.0032	-.0034	-.0034	-.0033	-.0030	-.0028	-.0020	-.0012	-.0002
.0010	.0024	.0041	.0061	.0083	.0104	.0124	.0139	.0148	.0147	.0138	.0123	.0104	.0083	.0063
.0048	.0031	.0018	.0008	.0000	-.0006	-.0011	-.0014	-.0017	-.0018	-.0018	-.0018	-.0018	-.0013	-.0010
-.0005	.0000	.0007	.0015	.0024	.0034	.0045	.0055	.0065	.0072	.0078	.0075	.0070	.0063	.0053
.0043	.0033	.0024	.0017	.0010	.0005	.0001	-.0002	-.0005	-.0007	-.0008	-.0009	-.0009	-.0008	-.0007
-.0008	-.0004	-.0002	.0001	.0004	.0008	.0012	.0018	.0020	.0025	.0028	.0031	.0032	.0032	.0030
.0028	.0022	.0018	.0014	.0010	.0007	.0005	.0003	.0001	-.0001	-.0002	-.0002	-.0003	-.0003	-.0003
-.0003	-.0002	-.0002	-.0001	-.0000	.0001	.0002	.0003	.0004	.0005	.0007	.0008	.0009	.0009	.0009
.0009	.0008	.0007	.0006	.0005	.0004	.0003	.0002	.0001	.0001	.0000	.0000	-.0000	-.0000	-.0001
-.0001	-.0001	-.0000	-.0000	-.0000	-.0000	-.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001
.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

VARIANCE FROM INTEGRATION OF ROTATIONAL S(M)
 COMPUTED BY FFT OF ACF 2.015615 (M/S)**2
 VON KARMAN S(N) SPECTRUM

77.119100	64.199300	50.645970	39.519820	31.140640	24.961910	20.380510	16.931080	14.286120	12.220690
10.579980	9.258147	8.172865	7.275158	6.522765	5.885717	5.341370	4.872370	4.465247	4.109420
3.796487	3.519703	3.273612	3.053752	2.856452	2.678666	2.517850	2.371066	2.238904	2.117427
2.006118	1.903849	1.809642	1.722653	1.642145	1.567474	1.498075	1.433451	1.373163	1.316821
1.264081	1.214633	1.168202	1.124542	1.083429	1.044666	1.008070	.973480	.940747	.909738
.880329	.852411	.825881	.800645	.776820	.753728	.731892	.711051	.691143	.672110

.653902	.636470	.619768	.603757	.588396	.573851	.559487	.545875	.532784	.520188
.508061	.498381	.485123	.474268	.463797	.453890	.443931	.434503	.425392	.416582
.408060	.399814	.391831	.384099	.378809	.369350	.362312	.355488	.348863	.342438
.338195	.330135	.324247	.318526	.312964	.307558	.302298	.297179	.292198	.287350
.282829	.278031	.273551	.269188	.264931	.260783	.256738	.252792	.248942	.245185
.241518	.237938	.234442	.231027	.227692	.224432	.221247	.218133	.215089	.212112
.209201	.206353	.203567	.200840	.198171	.195559	.193001	.190498	.188043	.185640
.183285	.180979	.178718	.176502	.174330	.172200	.170111	.168063	.166054	.164083
.162149	.160251	.158389	.156561	.154766	.153005	.151275	.149576	.147907	.146268
.144858	.143076	.141522	.139994	.138493	.137017	.135567	.134140	.132738	.131358
.130002	.128668	.127358	.126084	.124794	.123544	.122314	.121104	.119912	.118739
.117585	.116448	.115329	.114227	.113141	.112072	.111019	.109982	.108960	.107954
.106962	.105984	.105021	.104072	.103136	.102214	.101305	.100409	.099525	.098654
.097795	.096948	.096112	.095288	.094475	.093674	.092883	.092102	.091333	.090573
.089823	.089004	.088354	.087633	.086922	.086220	.085527	.084843	.084168	.083501
.082843	.082193	.081551	.080917	.080291	.079672	.079061	.078458	.077862	.077273
.078891	.078117	.077549	.074987	.074433	.073885	.073343	.072808	.072279	.071758
.071239	.070728	.070223	.069724	.069230	.068742	.068260	.067782	.067310	.066844
.066382	.065926	.065474	.065028	.064586	.064149	.063717	.063289	.062868	.062448
.062034	.061624	.061219	.060818	.060421	.060028	.059639	.059255	.058874	.058497
.058124	.057755	.057389	.057028	.056669	.056315	.055964	.055616	.055272	.054931
.054594	.054260	.053929	.053602	.053277	.052958	.052638	.052323	.052010	.051701
.051395	.051092	.050791	.050494	.050199	.049906	.049617	.049330	.049046	.048765
.048486	.048209	.047935	.047664	.047395	.047129	.046864	.046603	.046343	.046086
.045831	.045579	.045328	.045080	.044834	.044590	.044348	.044109	.043871	.043635
.043402	.043170	.042941	.042713	.042487	.042263	.042041	.041821	.041603	.041387
.041172	.040959	.040748	.040539	.040331	.040125	.039921	.039718	.039517	.039318
.039120	.038924	.038729	.038536	.038345	.038155	.037966	.037779	.037594	.037410
.037227	.037046	.036868	.036687	.036510	.036335	.036160	.035987	.035816	.035645
.035476	.035308	.035142	.034977	.034813	.034650	.034488	.034328	.034169	.034011
.033854	.033698	.033543	.033390	.033238	.033087	.032938	.032787	.032639	.032493
.032347	.032202	.032058	.031915	.031774	.031633	.031493	.031355	.031217	.031080
.030944	.030809	.030675	.030542	.030410	.030279	.030149	.030019	.029891	.029763
.029637	.029511	.029386	.029261	.029138	.029016	.028894	.028773	.028653	.028534
.028415	.028297	.028181	.028064	.027949	.027834	.027721	.027607	.027495	.027383
.027272	.027162	.027053	.026944	.026836	.026728	.026622	.026515	.026410	.026305
.026201	.026098	.025995	.025893	.025792	.025691	.025591	.025491	.025392	.025294
.025196	.025099	.025002	.024906	.024811	.024716	.024622	.024529	.024435	.024343
.024251	.024160	.024069	.023979	.023889	.023800	.023711	.023623	.023535	.023448
.023362	.023276	.023190	.023105	.023020	.022936	.022853	.022770	.022687	.022605
.022523	.022442	.022361	.022281	.022201	.022122	.022043	.021965	.021887	.021809
.021732	.021655	.021579	.021503	.021428	.021353	.021278	.021204	.021130	.021057
.020984	.020912	.020839	.020768	.020696	.020626	.020555	.020485	.020415	.020346
.020277	.020208	.020140	.020072	.020004	.019937	.019870	.019804	.019738	.019672
.019607	.019542	.019477	.019413	.019349	.019285	.019222	.019158	.019096	.019033
.018971	.018910	.018848	.018787	.018726	.018666	.018606	.018548	.018487	.018427
.018368	.018310	.018252	.018193	.018136	.018078	.018021	.017964	.017908	.017852
.017798	.017740	.017684	.017629	.017574	.017520	.017465	.017411	.017358	.017304
.017251	.017198	.017145	.017092	.017040	.016988	.016937	.016885	.016834	.016783
.016732	.016682	.016631	.016581	.016532	.016482	.016433	.016384	.016335	.016286
.016238	.016190	.016142	.016094	.016047	.016000	.015953	.015906	.015859	.015813
.015767	.015721	.015675	.015630	.015584	.015539	.015495	.015450	.015405	.015361
.015317	.015273	.015230	.015186	.015143	.015100	.015057	.015014	.014972	.014930
.014888	.014846	.014804	.014763	.014721	.014680	.014639	.014598	.014558	.014517
.014477	.014437	.014397	.014357	.014318	.014279	.014239	.014200	.014162	.014123

.014084	.014046	.014008	.013970	.013932	.013894	.013857	.013819	.013782	.013745
.013708	.013672	.013635	.013599	.013562	.013526	.013490	.013455	.013419	.013384
.013348	.013313	.013278	.013243	.013208	.013174	.013139	.013105	.013071	.013037
.013003	.012969	.012936	.012902	.012869	.012836	.012803	.012770	.012737	.012704
.012672	.012639	.012607	.012575	.012543	.012511	.012480	.012448	.012416	.012385
.012354	.012323	.012292	.012261	.012230	.012200	.012169	.012139	.012109	.012079
.012049	.012019	.011989	.011959	.011930	.011900	.011871	.011842	.011813	.011784
.011755	.011726	.011698	.011669	.011641	.011613	.011585	.011557	.011529	.011501
.011473	.011445	.011418	.011390	.011363	.011336	.011309	.011282	.011255	.011228
.011202	.011175	.011148	.011122	.011096	.011070	.011044	.011018	.010992	.010966
.010940	.010915	.010889	.010864	.010838	.010813	.010788	.010763	.010738	.010713
.010688	.010664	.010639	.010615	.010590	.010566	.010542	.010518	.010494	.010470
.010446	.010422	.010398	.010375	.010351	.010328	.010305	.010281	.010258	.010235
.010212	.010189	.010166	.010143	.010121	.010098	.010076	.010053	.010031	.010009
.009986	.009964	.009942	.009920	.009898	.009877	.009855	.009833	.009812	.009790
.009769	.009747	.009726	.009705	.009684	.009663	.009642	.009621	.009600	.009579
.009558	.009538	.009517	.009497	.009476	.009456	.009436	.009416	.009395	.009375
.009355	.009335	.009316	.009296	.009276	.009256	.009237	.009217	.009198	.009178
.009159	.009140	.009121	.009101	.009082	.009063	.009044	.009026	.009007	.008988
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.008786	.008768	.008750	.008732	.008714	.008696	.008678	.008661	.008643	.008626
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.008438	.008419	.008402	.008386	.008369	.008352	.008336	.008319	.008302	.008286
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.007511	.007497	.007483	.007469	.007455	.007441	.007427	.007413	.007400	.007386
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.007238	.007225	.007212	.007198	.007185	.007172	.007159	.007146	.007133	.007120
.007107	.007095	.007082	.007069	.007056	.007044	.007031	.007018	.007006	.006993
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S(N) ESTIMATES FROM FFT OF ACF

11.128880	10.865700	10.115420	8.986814	7.633777	6.222405	4.898658	3.784678	2.868720	2.209162
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1.850004	1.854757	1.859516	1.864281	1.869052	1.873829	1.878612	1.883401	1.888196	1.892997
1.897804	1.902617	1.907436	1.912261	1.917092	1.921929	1.926772	1.931621	1.936476	1.941337
1.946204	1.951077	1.955956	1.960841	1.965732	1.970629	1.975532	1.980441	1.985356	1.990277
1.995204	2.000137	2.005076	2.010021	2.014972	2.019929	2.024892	2.029861	2.034836	2.039817
2.044804	2.049797	2.054796	2.059801	2.064812	2.069829	2.074852	2.079881	2.084916	2.089957
2.095004	2.100057	2.105116	2.110181	2.115252	2.120329	2.125412	2.130501	2.135596	2.140697
2.145804	2.150917	2.156036	2.161161	2.166292	2.171429	2.176572	2.181721	2.186876	2.192037
2.197204	2.202377	2.207556	2.212741	2.217932	2.223129	2.228332	2.233541	2.238756	2.243977
2.249204	2.254437	2.259676	2.264921	2.270172	2.275429	2.280692	2.285961	2.291236	2.296517
2.301804	2.307097	2.312396	2.317701	2.323012	2.328329	2.333652	2.338981	2.344316	2.349657
2.355004	2.360357	2.365716	2.371081	2.376452	2.381829	2.387212	2.392601	2.398000	2.403407
2.408824	2.414247	2.419676	2.425111	2.430552	2.436000	2.441455	2.446916	2.452384	2.457857
2.463336	2.468817	2.474304	2.479797	2.485296	2.490801	2.496312	2.501829	2.507352	2.512881
2.518416	2.523957	2.529504	2.535057	2.540616	2.546181	2.551752	2.557329	2.562912	2.568501
2.574096	2.579697	2.585304	2.590917	2.596536	2.602161	2.607792	2.613429	2.619072	2.624721
2.630376	2.636037	2.641704	2.647377	2.653056	2.658741	2.664432	2.670129	2.675832	2.681541
2.687256	2.692977	2.698704	2.704437	2.710176	2.715921	2.721672	2.727429	2.733192	2.738961
2.744736	2.750517	2.756304	2.762097	2.767896	2.773701	2.779512	2.785329	2.791152	2.796981
2.802816	2.808657	2.814504	2.820357	2.826216	2.832081	2.837952	2.843829	2.849712	2.855601
2.861496	2.867397	2.873304	2.879217	2.885136	2.891061	2.896992	2.902929	2.908872	2.914821
2.920776	2.926737	2.932704	2.938677	2.944656	2.950641	2.956632	2.962629	2.968632	2.974641
2.980656	2.986677	2.992704	2.998737	3.004776	3.010821	3.016872	3.022929	3.028992	3.035061
3.041136	3.047217	3.053304	3.059397	3.065496	3.071601	3.077712	3.083829	3.089952	3.096081
3.102216	3.108357	3.114504	3.120657	3.126816					

.90000	1.8	.227389	.071549	2.90000	5.8	.076002	.010180
.95000	1.9	.078741	.065385	2.95000	5.9	.125600	.009894
1.00000	2.0	5.442014	.060028	3.00000	6.0	.173581	.009021
1.05000	2.1	.553394	.055341	3.05000	6.1	.118747	.009359
1.10000	2.2	.079975	.051213	3.10000	6.2	.071117	.009109
1.15000	2.3	.016584	.047558	3.15000	6.3	.046984	.008869
1.20000	2.4	.005454	.044300	3.20000	6.4	.035976	.008640
1.25000	2.5	.009285	.041387	3.25000	6.5	.032837	.008419
1.30000	2.6	.023064	.038768	3.30000	6.6	.035696	.008208
1.35000	2.7	.053761	.036405	3.35000	6.7	.044888	.008005
1.40000	2.8	.133513	.034284	3.40000	6.8	.082359	.007809
1.45000	2.9	.444815	.032318	3.45000	6.9	.089420	.007622
1.50000	3.0	1.773011	.030542	3.50000	7.0	.109143	.007441
1.55000	3.1	.342878	.028918	3.55000	7.1	.088138	.007287
1.60000	3.2	.090228	.027428	3.60000	7.2	.059520	.007100
1.65000	3.3	.035597	.028057	3.65000	7.3	.043241	.006938
1.70000	3.4	.020714	.024792	3.70000	7.4	.034968	.006783
1.75000	3.5	.020223	.023823	3.75000	7.5	.032300	.006633
1.80000	3.6	.029634	.022539	3.80000	7.6	.034153	.006488
1.85000	3.7	.053437	.021533	3.85000	7.7	.040478	.006348
1.90000	3.8	.111245	.020597	3.90000	7.8	.051701	.006213
1.95000	3.9	.280765	.019725	3.95000	7.9	.068729	.006083
2.00000	4.0	.674943	.018910	4.00000	8.0	.075629	.005958

SPECTRAL DENSITY FOR 20 DIVISIONS OF LOWEST FREQUENCY BAND
FREQUENCIES

.002500	.005000	.007500	.010000	.012500	.015000	.017500	.020000	.022500	.025000
.027500	.030000	.032500	.035000	.037500	.040000	.042500	.045000	.047500	.050000
S(N)									
11.02	10.70	10.19	9.52	8.73	7.86	6.95	6.06	5.20	4.42
3.72	3.13	2.63	2.23	1.91	1.66	1.47	1.31	1.18	1.08

SUMS OF S(N) FOR THE TWO SERIES 37.97 100.98
VARIANCE OF S(N) ON THIS PAGE, S(N)C 2.1508 (M/S)**2
LENGTH SCALE FROM INTEGRATION OF ACF IS 12.2 M
VARIANCES FOR FIRST HALF-P AND FOR 6P FROM 80-MEMBER SPECTRUM
S(N)C, - (M/S)**2

.3032	1.1178	.3692	.1469	.0797	.0524	.0383
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RMS

.5508	1.0573	.0077	.3833	.2823	.2289	.1957
SAME VARIANCES COMPUTED BY INTEGRATING THE VON KARMAN SPECTRUM, SVK(N)CA						
.7004	.1058	.0301	.0152	.0094	.0065	.0048

VARIANCES FOR FIRST HALF-P AND FOR 6P FROM
SPECTRUM OF SIMULATED DATA, S(N)R

.3083	1.0184	.3409	.1394	.0781	.0521	.0382
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SPECTRAL ESTIMATES FROM SIMULATED DATA
FIRST NUMBER IS SERIES MEAN

.0000	10.8657	10.1154	8.9868	7.6338	6.2224	4.8987	3.7647	2.8687	2.2092
1.7490	1.4348	1.2140	1.0468	.9087	.7904	.6902	.6087	.5455	.4972
.4592	.4289	.3976	.3705	.3484	.3261	.3100	.2974	.2870	.2776
.2686	.2600	.2523	.2459	.2409	.2372	.2341	.2312	.2284	.2258
.2232	.2215	.2204	.2199	.2197	.2195	.2192	.2190	.2191	.2196
.2205	.2217	.2230	.2243	.2258	.2271	.2287	.2308	.2331	.2357
.2383	.2410	.2437	.2467	.2499	.2535	.2574	.2615	.2657	.2701
.2746	.2794	.2846	.2904	.2965	.3028	.3094	.3162	.3234	.3312
.3398	.3488	.3585	.3687	.3793	.3904	.4024	.4155	.4298	.4454
.4620	.4798	.4982	.5180	.5398	.5639	.5908	.6203	.6524	.6867

.7238	.7648	.8185	.8829	.9228	.9898	1.0845	1.1471	1.2398	1.3484
1.4725	1.6236	1.8043	2.0178	2.2680	2.5637	2.9238	3.3814	3.9835	4.7838
5.8290	7.1398	8.6918	10.4058	12.1450	13.7331	14.9807	15.7221	15.8493	15.3358
14.2423	12.7059	10.9098	9.0480	7.2901	5.7560	4.5058	3.5429	2.8314	2.3141
1.9321	1.6378	1.3994	1.2001	1.0328	.8944	.7819	.6908	.6155	.5510
.4940	.4429	.3976	.3583	.3250	.2968	.2724	.2504	.2301	.2114
.1944	.1795	.1686	.1554	.1455	.1364	.1277	.1196	.1122	.1057
.1000	.0951	.0907	.0866	.0826	.0789	.0755	.0728	.0701	.0680
.0661	.0644	.0626	.0611	.0597	.0586	.0578	.0572	.0568	.0563
.0559	.0557	.0556	.0557	.0559	.0564	.0569	.0574	.0581	.0588
.0598	.0609	.0622	.0636	.0651	.0668	.0686	.0704	.0728	.0750
.0776	.0804	.0834	.0866	.0901	.0939	.0981	.1027	.1077	.1130
.1188	.1250	.1319	.1396	.1481	.1574	.1677	.1789	.1913	.2051
.2206	.2383	.2583	.2810	.3064	.3353	.3684	.4070	.4527	.5071
.5718	.6487	.7408	.8532	.9944	1.1766	1.4145	1.7229	2.1119	2.5825
3.1213	3.6990	4.2710	4.7827	5.1776	5.4076	5.4420	5.2737	4.9210	4.4240
3.8371									

VARIANCE OF S(N)R FROM SIMULATED DATA 2.0156
 SMOM(1), SMOM(2) .0000 2.0156
 SKEWNESS AND KURTOSIS -.1603 3.0044
 HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED
 24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE
 BANDED NSN SPECTRA

BAND CENTER, HI, LOW (HZ), NS(N), HARMONIC COUNT PER BAND [NS(N):ORIG	SIM	VK	VKA]
3.56500 4.00000 3.17731 211 814 1024	.19372	.19372	.02114 .02568
2.83178 3.17731 2.52383 168 647 814	.23595	.23595	.02462 .02991
2.24937 2.52383 2.00475 134 514 647	.30112	.30112	.02869 .03485
1.78673 2.00475 1.59243 106 409 514	.21868	.21868	.03340 .04057
1.41925 1.59243 1.26491 85 325 409	.57161	.57161	.03887 .04721
1.12735 1.26491 1.00475 68 258 325	.59051	.59051	.04533 .05506
.89549 1.00475 .79810 54 205 258	.93335	.93335	.05286 .06421
.71131 .79810 .63396 43 163 205	.05571	.05571	.06157 .07478
.56502 .63396 .50357 34 130 163	1.71228	1.71227	.07149 .08682
.44881 .50357 .40000 28 103 130	2.48508	2.48507	.08324 .10109
.35850 .40000 .31773 22 82 103	.18553	.18553	.09708 .11787
.28318 .31773 .25238 17 66 82	.08337	.08337	.11173 .13562
.22494 .25238 .20047 15 52 66	.05283	.05283	.12987 .15733
.17867 .20047 .15924 11 42 52	.03931	.03931	.15005 .18193
.14193 .15924 .12649 10 33 42	.03321	.03321	.17393 .21065
.11274 .12649 .10048 7 27 33	.03145	.03145	.19934 .24102
.08955 .10048 .07981 7 21 27	.03373	.03373	.23017 .27756
.07113 .07981 .06340 5 17 21	.03984	.03984	.26756 .32130
.05850 .06340 .05036 4 14 17	.04853	.04853	.29600 .35349
.04488 .05036 .04000 4 11 14	.06109	.06109	.33453 .39589
.03585 .04000 .03177 3 9 11	.08113	.08113	.37733 .44072
.02832 .03177 .02524 3 7 9	.10885	.10885	.42557 .48705
.02249 .02524 .02005 2 6 7	.12506	.12508	.45813 .50996
.01787 .02005 .01592 2 5 6	.12379	.12379	.46019 .50120

UNBANDED NSN SPECTRA

.003906	.042444	.042444	.286714	.250779
.007813	.079027	.079027	.411708	.395872
.011719	.105314	.105314	.450712	.463123

ANALYSIS OF SIMULATED DATA INCLUDING MEAN WIND EFFECT

A, B, AMP, ANGLE IN DEGREES -.3415 -.0848 .3519 -166.0503
 PHASE ANGLE FOR 1P IN SIMULATED DATA -166.1 DEGREES

OFFSET ANGLE BETWEEN MEAN WIND AND TURBULENCE AT 1P (DELAY) .0 DEGREES
 OFFSET, IFFSET, -7.4 11
 ONE CYCLE OF MEAN WIND EFFECT - M/S
 -3.83 .00 3.83 7.07 9.24 10.00 9.24 7.07 3.83 .00 -3.83 -7.07 -9.24 -10.00 -9.24 -7.07
 NUMBER OF COMPLETE MEAN WIND CYCLES IN SIMULATION 128
 VARIANCES FOR FIRST HALF-P AND FOR 8P FROM
 SPECTRUM OF SIMULATED DATA, S(N)R
 .3083 51.5418 .3409 .1394 .0781 .0521 .0382

SPECTRAL ESTIMATES FROM SIMULATED DATA

FIRST NUMBER IS SERIES MEAN

.0000	10.8657	10.1154	8.9868	7.8338	6.2224	4.8987	3.7847	2.8687	2.2092
1.7490	1.4348	1.2140	1.0468	.9087	.7904	.6902	.6087	.5455	.4972
.4692	.4269	.3976	.3705	.3464	.3281	.3100	.2974	.2870	.2778
.2686	.2600	.2523	.2459	.2409	.2372	.2341	.2312	.2284	.2256
.2232	.2215	.2204	.2199	.2197	.2195	.2192	.2190	.2191	.2196
.2205	.2217	.2230	.2243	.2256	.2271	.2287	.2308	.2331	.2357
.2383	.2410	.2437	.2467	.2499	.2535	.2574	.2615	.2657	.2701
.2746	.2794	.2846	.2904	.2965	.3028	.3094	.3162	.3234	.3312
.3396	.3488	.3585	.3687	.3793	.3904	.4024	.4155	.4298	.4454
.4620	.4798	.4982	.5180	.5398	.5639	.5908	.6203	.6524	.6867
.7238	.7646	.8105	.8629	.9226	.9898	1.0645	1.1471	1.2398	1.3484
1.4725	1.6236	1.8043	2.0178	2.2680	2.5637	2.9238	3.3614	3.9835	4.7838
5.8290	7.1398	8.8918	10.4058	12.1450	13.7331	14.9807	15.7221	12949.7900	15.3358
14.2423	12.7059	10.9098	9.0480	7.2901	5.7500	4.5058	3.5429	2.8314	2.3141
1.9321	1.6378	1.3994	1.2001	1.0328	.8944	.7819	.6908	.6155	.5510
.4940	.4429	.3976	.3583	.3250	.2968	.2724	.2504	.2301	.2114
.1944	.1795	.1668	.1554	.1455	.1384	.1277	.1196	.1122	.1057
.1000	.0951	.0907	.0866	.0828	.0789	.0755	.0726	.0701	.0680
.0681	.0644	.0628	.0611	.0597	.0588	.0578	.0572	.0568	.0563
.0559	.0557	.0558	.0557	.0559	.0564	.0569	.0574	.0581	.0588
.0598	.0609	.0622	.0636	.0651	.0668	.0685	.0704	.0728	.0750
.0776	.0804	.0834	.0866	.0901	.0939	.0981	.1027	.1077	.1130
.1188	.1250	.1319	.1396	.1481	.1574	.1677	.1789	.1913	.2051
.2206	.2383	.2583	.2810	.3064	.3353	.3684	.4070	.4527	.5071
.5718	.6467	.7408	.8532	.9944	1.1768	1.4145	1.7229	2.1119	2.5825
3.1213	3.8990	4.2710	4.7627	5.1776	5.4076	5.4420	5.2737	4.9210	4.4240

3.8371

VARIANCE OF S(N)R FROM SIMULATED DATA 52.5389

SMOM(1), SMOM(2) .0000 52.5388

SKENNESS AND KURTOSIS -.0574 1.6047

HALF-RANDOMIZING SIMULATION - PHASE RANDOMIZED

24 LOGARITHMICALLY SPACED BANDS AT 10. PER SPECTRAL DECADE

BANDED NSM SPECTRA

BAND CENTER, HI, LOW (HZ),	NS(N),	HARMONIC COUNT PER BAND	[NS(N):ORIG	SIM	VK	VKA]	
3.58500	4.00000	3.17731	211 814 1024	.19372	.19372	.02114	.02568
2.83178	3.17731	2.52383	168 647 814	.23595	.23595	.02482	.02991
2.24937	2.52383	2.00475	134 514 647	.30112	.30112	.02869	.03485
1.78873	2.00475	1.59243	106 409 514	.21888	.21888	.03340	.04057
1.41925	1.59243	1.28491	85 325 409	.57181	.57181	.03887	.04721
1.12735	1.28491	1.00475	68 258 325	.59051	.59051	.04533	.05506
.89549	1.00475	.79810	54 205 258	.93335	.93335	.05286	.06421
.71131	.79810	.63398	43 163 205	.05571	.05571	.06157	.07478
.56502	.63398	.50357	34 130 163	1.71228	1.71227	.07149	.08662
.44881	.50357	.40000	26 103 130	2.48508	209.60110	.08324	.10109
.35650	.40000	.31773	22 82 103	.18553	.18553	.09708	.11767

.28318	.31773	.25238	17	88	82	.08337	.08337	.11173	.13582
.22494	.25238	.20047	15	52	86	.05283	.05283	.12987	.15733
.17867	.20047	.15924	11	42	52	.03931	.03931	.15005	.18193
.14193	.15924	.12849	10	33	42	.03321	.03321	.17393	.21065
.11274	.12849	.10048	7	27	33	.03145	.03145	.19934	.24102
.08955	.10048	.07981	7	21	27	.03373	.03373	.23017	.27758
.07113	.07981	.06340	5	17	21	.03984	.03984	.26758	.32130
.05850	.06340	.05036	4	14	17	.04853	.04853	.29800	.35349
.04488	.05036	.04000	4	11	14	.06109	.06109	.33453	.39589
.03565	.04000	.03177	3	9	11	.08113	.08113	.37733	.44072
.02832	.03177	.02524	3	7	9	.10885	.10885	.42557	.48705
.02249	.02524	.02005	2	6	7	.12508	.12508	.45813	.50998
.01787	.02005	.01592	2	5	6	.12379	.12379	.48019	.50120
UNBANDIED NSN SPECTRA									
.003906	.042444	.042444	.286714	.250779					
.007813	.079027	.079027	.411708	.395872					
.011719	.105314	.105314	.450712	.483123					

2048	1.186722	-4.108525E-01	-9.239280E-01	1.280088
8.417682E-01	-7.111245E-02	2.189247E-01	1.119541	
2.492373	4.383997E-01	-1.867283E-01	1.488686	
1.327165	-1.142121E-01	-8.078572E-01	4.690985E-01	
1.128359	1.320451	9.819438E-02	1.835883	
2.097834	1.982905	4.948867E-01	1.900083	
1.228778	8.902582E-01	-3.315728E-01	1.277614	
1.865971	5.047071E-01	-5.940647E-01	1.741713E-01	
1.494968	1.172362	5.330315E-02	2.183839E-01	
7.991824E-01	-1.540351E-01	-1.818853E-01	4.632374E-01	
1.399042	4.019439E-02	2.885438E-01	1.714614	
2.710489	9.930547E-01	-9.205768E-01	-1.986542E-02	
9.426385E-01	2.981740E-01	9.184483E-02	-4.883447E-01	
-1.732058	-1.804249	-1.878095E-01	5.578286E-01	
1.052483	1.221345E-01	7.635987E-01	1.034115	
1.450585	1.001370	-7.411526E-01	4.840232E-01	
2.821863E-01	-4.255363E-01	8.690820E-01	-4.448661E-02	
-1.821808	-2.298895	-1.994195	-5.889882E-01	
2.463082E-01	-8.345717E-02	1.242085	9.851739E-01	
1.743740E-01	3.728944E-01	-1.294043E-01	-8.970807E-01	
-1.314909	-1.234424	1.714434E-01	-4.804012E-01	
-2.275418	-2.505100	-1.281189	-4.813380E-01	
5.443028E-01	1.348767	1.921684	8.320500E-01	
1.379811	1.833337	3.688056E-01	-3.947983E-01	
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APPENDIX G

SUPPLEMENTARY BIBLIOGRAPHY

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