RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL

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ADMINISTRATIVE STATEMENT

The work reported herein was performed under NAVSHIPS Project No. SF 55 2070 by members of the Acoustic Environmental Modeling Division. The paper covers work from June 1971 to October 1972.

Released by
L. K. ARNDT, Head
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SUMMARY

PROBLEM

Develop a computer model for calculating the vertical and horizontal directionality of low-frequency ambient noise for an ocean environment.

RESULTS

A FORTRAN computer model has been developed. The Research Ambient Noise Directionality Model (RANDI) has given results in good agreement with measured data for the Pacific, Atlantic, and the Mediterranean.

RECOMMENDATIONS

RANDI noise calculations should be compared with ambient noise measurements for other ocean areas, seasons, and noise-source distributions as data, sufficiently documented for validation purposes, become available.
A computer model for calculating the vertical and horizontal directionality of ambient noise and some of the results which have been obtained are discussed. The model considers three sources of surface-generated anisotropic noise, one source of surface-generated isotropic noise and two sources of volumetric isotropic noise. Noise levels are obtained for various propagation conditions and for different sensor depths. Results agree well with experimental data, and it is shown that the model can be a useful tool in the planning of ambient noise measurement experiments and in the analysis of results.
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INTRODUCTION

The Research Ambient Noise Directionality Model (RANDI) is an operating general-purpose FORTRAN Program that calculates and displays, via CALCOMP plots, the vertical and horizontal directionality of low-frequency (between 10 and 500 Hz) ambient noise for an ocean environment. This first-phase program will be used in the design of ambient noise measurement experiments and in surveillance systems analysis studies. A variable-dependent approach based on system and environmental parameter variance makes this model inappropriate for synoptic forecasting. It will be improved and validated as time, data, and state-of-the-art permit.

BACKGROUND

The ambient noise at any particular point in the ocean depends upon the amount and location of noise-generating sources and the nature of the local acoustic propagation conditions, i.e., how the noise gets from the generator to the measuring sensor.

Sound in the ocean travels in curved or refracted paths and will arrive at a hydrophone from various vertical angles, depending on the depth of the source and the hydrophone and on the separation range. The path an individual sound ray travels can include surface reflections and bottom bounces, as illustrated in the ray diagram (Fig. 1). The bottom bounce paths will generally have the highest sound energy losses, while the paths which do not make contact with either the surface or the bottom will have the smallest transmission losses. The vertical angle between one of these latter rays and the horizontal is generally less than 15 deg at any range, while the rays making contact with the surface or bottom can have vertical angles approaching 90 deg. This effectively divides the sound rays into three distinct groups: (1) rays which come in contact with the bottom and arrive at angles from approximately 15 to 90 deg down from the horizontal; (2) the near-horizontal or SOFAR Channel rays, which touch neither surface nor bottom and. (3) the rays arriving at angles above 15 deg and which originated or were reflected from near the surface.

There are many sources of noise, the most important being winds, waves, shipping, thermal agitation and biological and seismic activity. The noise due to winds, waves, and shipping originates near the surface and arrives at the sensor along paths which travel near or reflect from the surface. In the case of distant sources, the noise travels by way of the SOFAR Channel and will arrive, at a sensor located within the channel, from nearly horizontal angles. Noise from near sources (within a few hundred miles) will arrive at angles closer to the vertical than does the SOFAR Channel noise. Thermal noise comes from throughout the medium and can arrive at any angle or from any direction. Seismic noise would be expected to arrive along those paths which come in contact with radiating or reflecting surfaces, including the bottom and distant seamounts. Biological noise, however, originates along the surface, the bottom, and throughout the medium.
The net effect of propagating—towards the sensor—the noises from such a highly stratified distribution of noise generators is a noise field having vertical directionality, i.e., noise level dependent on vertical arrival angle, as illustrated in Fig. 2.

Various ambient noise models have been proposed which include part of the major noise sources and invoke certain simplifying assumptions to produce a medium less hostile to mathematical description in an attempt to render the problem solvable and yet obtain meaningful results. Few investigators have succeeded, and then only in highly specialized cases. There is documentation on several of these ambient noise directionality models. In the opinion of the author, none is adequate for use in the design of detailed directional noise measurement experiments or for use in surveillance systems analysis studies. Miller (Ref. 1) and Urick (Ref. 2), for example, proposed theoretical models which require a zero sound-speed gradient. These models cannot account for surface-generated noise arriving at angles below the horizontal or for bottom noise (biological, seismic) arriving at angles above the horizontal, except by reflection from the bottom or surface, respectively. This results in a distorted directional noise pattern with abnormally low levels near the horizontal. Talham's model (Ref. 3), on the other hand, includes realistic sound-speed profiles but applies only to bottom-mounted hydrophones. Bartberger (Ref. 4) considered only ship
noise from a uniform distribution of surface ships, thus restricting the usefulness of his model to the 20- to 100-Hz region. Finally, the MOSS Ambient Noise Model developed jointly by the Navy and Bell Telephone Laboratories calculates the expected vertical directionality of the noise field for seven ocean areas for the mean summer and winter conditions for acoustic propagation, wind speed, and shipping. A more general area-independent model is desired.

In addition to the limitations already discussed, none of the above models considers horizontal directionality, noise due to distant sources (SOFAR Channel noise), or noise of a biological or transient nature, nor does any contain sufficient provision for considering variances in system characteristics. For these reasons RANDI was developed for use in the design of ambient noise measurement experiments and the analysis of surveillance systems.

**AMBIENT NOISE DIRECTIONALITY MODEL

MODEL DESCRIPTION

RANDI utilizes one or two of three different sources for the propagation loss between the noise generators and the sensor. The first source is a self-contained linear raytrace routine, one which approximates the sound-speed profile by a series of straight-line segments and corrects for earth curvature. See Ref. 5 for a detailed description.

The second source is a set of propagation loss versus range and arrival angle arrays which is input as data. If the propagation loss is input, RANDI will bypass the raytrace routine. Hence, ambient noise calculations by RANDI can be based on propagation loss values from ray theory (its own or nearly any other raytrace model, including those that account for variable bottom topography and horizontal changes in the sound-speed profile),
normal-mode theory, experimental measurements, or any method by which propagation loss versus range and arrival angle might be obtained. This second source of propagation loss can be extremely useful when operating RANDI at the relatively low frequencies of many passive surveillance systems, where the validity of ray theory becomes questionable and normal-mode theory more attractive.

The third form of propagation loss utilized by RANDI is for sound energy traveling from distant sources to a sensor located within the SOFAR Channel. RANDI calculates the propagation loss in this case by considering the effects of frequency-dependent attenuation and spreading loss increasing with fifteen times the log of the average range to the continental shelf or the range to where the SOFAR Channel reaches the surface (as in northern latitudes).

In addition to distant noise, RANDI considers five other sources of isotropic and anisotropic surface and volumetric noise (Fig. 3): shipping, sea state 0, biological, rain, and wind-wave interaction.

The surface noise is generated by an infinite number of point sources distributed along a horizontal "noise source plane" just below the surface (Fig. 4). The depth of this plane is set at 20 ft, since the main ship noise radiators (screws, shaft, and hull) are near this depth, and surface wave action extends well below the surface. The shipping noise generators are nonuniformly distributed, while the wind-wave and rain noise generators are uniformly distributed. The noise resulting from any of these three sources is anisotropic. Sea state 0 and biological noises come from a uniform volumetric distribution of noise generators centered around the sensor and result in isotropic noise. The SOFAR Channel noise received by a sensor located within the SOFAR Channel is also isotropic for all channeled ray angles. The total noise field, then, is part isotropic and part anisotropic.

A target capability is also included in RANDI. By specifying the oceanographic, environmental and noise conditions, and a target location, depth, and frequency spectrum or line component, the Surveillance System Analyst receives, by way of plot and printed output, the levels and angles of target multiple arrivals superimposed on the ambient noise arrivals (see Figs. B-4 through B-13). Such a capability can make RANDI a useful tool in the design, analysis, and optimization of surveillance systems.

MATHEMATICAL DESCRIPTION

The anisotropic shipping noise squared pressure spectrum level SNL (for a 1-Hz band) in the model is obtained from surface noise generators which have a radiated sound pressure level varying with frequency. The following empirical expression, which has characteristics similar to the spectra given in Fig. 71 of Ref. 6, is utilized:

$$SNL (re \mu Pa) = A_0 - 10 \log (10^{-6.0 \log f + 1.16 + 10^{-3.3 \log f - 6.27}}) + 4 \text{ SHIPD} + 50 \log (\text{SPEED}/12) + 20 \log (\text{LENGTH}/300)$$
Figure 3. RANDI model block diagram.
where

\[ A_0 = \begin{cases} 90 & \text{no distant noise sources} \\ 85 & \text{distant noise sources specified} \end{cases} \]

\[ f' = f - 2 \text{ SHIPD} + 12 \]

\[ f = \text{number of hertz} \]

\[ \text{SHIPD} = \text{shipping density indicator} \ (0 - 7) \]

\[ \text{SPEED} = \text{number of knots of noise-source ships' average speed} \]

\[ \text{LENGTH} = \text{number of feet of noise-source ships' average length} \]

The squared pressures obtained from the levels given by this function are distributed over the noise source plane in such a way to result in effective squared pressures for unit area at unit distance (the mechanics are described in the section on model calibration) with magnitude varying in range and azimuth in such a manner to be proportional to the density of an input shipping density distribution \( \text{ASHIP} \) (ship density vs range array) or a shipping density indicator \( \text{SHIPD} \) (no shipping to heavy shipping on a scale from zero to seven). A similar expression was used for the squared pressure level due to distant sources \( \text{DSL} \), since shipping is the major contributor at low frequencies and the higher frequencies are severely attenuated at SOFAR Channel propagation ranges.

The squared pressure spectrum levels for the anisotropic noise \( \text{WNL} \) due to wind-wave interaction were obtained from a fit to the data of Perrone (Ref. 7) and are a function of wind speed and frequency as follows:
WNL (re $\mu$Pa) = $-18 \log f + 96$

$$+ [9.66 (\log f)^2 - 26 \log f + 27.3] (0.065 \text{WSPD}^{0.3})$$

where WSPD = number of knots of wind speed in the vicinity of the sensor.

These levels are converted into mean squared sound pressure in a 1-Hz band and further modified by a multiplying factor to achieve directionality of the source at high frequencies and nondirectionality at the lower frequencies as indicated by Becken (Ref. 8). The wind noise squared pressure modifier used in the model is the following:

Squared pressure multiplier = $1 - (1 - \cos^n \phi) (0.002 f - 0.02)$

where $\phi$ = angle (in degrees) from the vertical that the ray makes at the source, and

$$n = \begin{cases} 
90 - \phi & 0 \leq \phi \leq 70 \\
10 & 70 < \phi \leq 90 
\end{cases}$$

The following function, obtained from the data of Franz (Ref. 9), gives, for rain, the expected noise squared pressure level RPL in a 1-Hz band and is distributed uniformly along the horizontal noise plane in a manner similar to the wind-wave noise.

$$RPL \ (re \ \mu Pa) = 5.5 \log f + 50.5 + 14.5 \log (\text{RAIN})$$

where RAIN is the number of inches of rainfall per hour in the vicinity of the sensor.

Isotropic sea state 0 noise squared pressure spectrum level SS0 is that noise which is measured under the ideal conditions of no wind, calm surface, no biological activity, and negligible shipping. It varies with frequency and is independent of depth and geographic location. The equation for SS0 (for a 1-Hz band) was obtained by a quadratic fit to data of Wenz (Ref. 10):

$$SS0 \ (re \ \mu Pa) = 4.22 (\log f)^2 - 33.4 \log f + 89.1$$

A volumetric or isotropic distribution was chosen for biological noise in the absence of data indicating otherwise. This noise varies with time of day and relative amount of activity expected at a particular site. An activity indicator on a scale from zero to ten is an input to the model. The equation for the biological noise squared pressure spectrum level BPL is of the following form:

$$BPL \ (re \ \mu Pa) = 0.00175 (100 - f) \sin [0.00262 (hr - 300)] \text{ACTIVITY}$$

$$- 16.96 (\log f)^2 + 50.1 \log f + 45.1$$
where the $0 \leq \text{ACTIVITY} \leq 10$ and $hr$ is the local time of day (military designation 0000-2400).

The sound pressure spectrum level $TSL$ for a target source is accepted by the model by reading in the appropriate coefficients $A_i$, $i = 1, 3$, of a third-degree polynomial

$$TSL = A_3 \log \left( f \right)^3 + A_2 \log \left( f \right)^2 + A_1 \log f + A_0$$

In the event that the line component is the dominant feature in the band of interest, $A_0$ is the level of the line. Also specified by the user are the initial target range and depth, the numbers of target ranges and depths to be calculated, and the increments in range and depth to be used.

COMPUTATIONAL PROCEDURE

All of the noise and target squared pressure spectrum levels are integrated over a user-specified bandwidth by means of an input frequency response function. If none is specified, a 1-Hz bandwidth and a constant bandpass frequency response function are assumed.

The squared pressure received for a differential vertical angle is obtained by first calculating the area defined by the intersections of the corresponding ray bundle with the noise source plane. These areas are multiplied by the local effective squared noise pressures for unit area at a distance of 1 yard. The resulting squared pressures are then reduced to account for propagation loss and summed. To this value is added the contribution of the isotropic noise sources. The result is further reduced to account for the vertical response of an individual hydrophone or an array of hydrophones. If no response function is specified, it is assumed omnidirectional. The final squared noise pressure arriving at that angle is stored for output and the process is repeated for an adjacent ray bundle at a new vertical angle.

In the case where horizontal directionality is desired, the ocean is divided into $n$ regions by passing vertical planes through the sensor location at $360/n$ deg. The ocean is then effectively divided into $n$ regions, similar to a huge sliced pie of infinite radius whose thickness is equal to the ocean depth at the receiver location. The pertinent environmental and noise parameters are specified separately for each "pie slice" region. Hence, the calculations performed for one region are independent of the calculations performed in adjacent regions. The total squared noise pressure, that which would be measured by an omnidirectional hydrophone, is obtained by summing the squared noise pressures for the $n$ independent "pie slice" regions. An example is given in Appendix B, Figs. B-6 through B-11.

An explanation of terminology used in the ambient noise directionality illustrations is necessary before results can be interpreted. Noise level refers to the per steradian mean squared pressure spectrum level. Vertical received angle is the angle at the sensor the incident ray makes with the horizontal. The negative rays are downcoming rays at the sensor, with the ray having a vertical received angle of $-90$ deg being the ray which arrives from
the surface directly above the sensor. The rays with positive angles arrive at the sensor from angles below the horizontal.

Unlike noise, targets are treated as point sources at specific ranges and depths. However, the received signal squared pressures are similarly influenced by the bandwidth, frequency response function, and the vertical beam response function.

To aid the user, many of the model inputs have been initialized in data statements. This eliminates the repeated input of variables which are common to many situations and yet allows the initial values to be suppressed in the event that different values are desired. Those parameters which have been initialized are given in the model input section of the program listing. Appendix C.

MODEL CALIBRATION PROCEDURE

The functional relationships used for noise express the pressure spectrum levels one would expect to measure and are not source levels. To get the effective source levels at a distance of 1 yard (for unit surface area) for distributions of noise generators requires removing from the original levels the effects of frequency-dependent attenuation in the medium and then normalizing to a unit of surface area. This is accomplished by distributing the noise generators along the horizontal noise plane and propagating the noise at different frequencies. A calibration function can then be obtained which is added to the original levels to yield corrected levels and eliminate bias. This effectively removes the effects of frequency attenuation in the original levels and converts them to source levels for unit surface area. Finally, the output of the model is adjusted to coincide with measured data for one set of conditions (frequency, depth, wind speed, etc.) at one location.

This calibration is dependent on the manner in which the noise sources are distributed and the method by which the noise generation area is calculated and is independent of the medium. Hence, once this calibration is performed for one set of conditions at one location, it need not be done for other conditions or locations. The initial calibration was performed using Marine Physical Laboratory (MPL) Pacific ambient noise data (Ref. 11) and shipping information provided by Western Seas Frontier.

MODEL VALIDATION

The final step, validation, has not yet been completed. This requires comparing the model output with measured data for many different locations, seasons, depths, frequencies, shipping distributions, wind speeds, etc. Tentative plans include comparing with the IOMEDEX data, which were taken in the Mediterranean during November 1971. Comparison with other data sets for different conditions will be done as data become available. Although a large quantity of data is now readily available, the lack of shipping information for the time interval during which the measurements were taken disqualifies it. Nearly all historical ambient noise data are inappropriate for model validation.
DISCUSSION OF RESULTS

GENERAL RESULTS

Examples of output from the model for three different geographic locations (Fig. 5) have been included to illustrate both the capability of the model and variability in the directional character of the noise field resulting from differences in sensor depth and acoustic propagation (Figs. 6, 7, and 8). Profiles which generally characterize summer conditions in the Pacific, Atlantic, and Mediterranean were chosen.

It is interesting to note the existence of the trough (low level of noise) in the noise field near the horizontal. This condition results from the horizontal rays at the hydrophone.

Figure 5. Sound-speed profiles for Areas 1, 2, and 3.
Figure 6. Vertical directionality of ambient noise at four different depths for Area 1.
Figure 7. Vertical directionality of ambient noise at four different depths for Area 2.
Figure 8. Vertical directionality of ambient noise at four different depths for Area 3.
being unable to reach the surface, where the wind and shipping noise is generated. In two cases, as the depth increases, the trough becomes narrower and eventually disappears, indicating that only near the bottom will the horizontal rays "see" the surface. In the other case, however, the trough gets wider as the depth increases. This results from the sound speed at the bottom being much less than that at the surface, hence, horizontal bottom rays can never reach the surface. Energy within the trough arrives from distant sources. The trough levels are determined by the amount of energy which has become trapped within the SOFAR Channel. There can be a trough, or it can be filled in, depending on whether the energy per arrival angle due to near sources is greater or less than that due to distant sources. The total amount of sound energy received from the distant sources depends on the total number of ships over the continental slope and shelf, range to the shelf, and the total channel "look" angle at the sensor depth.

The lower level of sound at down going angles, greater than approximately 15 deg, compared to the up going angles, less than −15 deg, results from bottom loss. The upcoming rays, having bounced off the bottom before reaching the receiver, suffer a loss in energy not experienced by rays coming from the surface. This accounts for the asymmetric shape of the noise plots.

**MODEL OUTPUT—MEASURED DATA COMPARISON**

Ambient noise data obtained by MPL (Ref. 11) during their April and May 1971 FLIP ambient noise measurements were utilized for the initial model calibration and to perform a level-variable dependence check.

The model was initially calibrated at 50 Hz and 100 m receiver depth by reading in the measured wind speed and recorded shipping data and adjusting the model output to correspond to the measured noise level for a single day of the 15-day series of measurements. The output of the model was then compared with the measured data for other frequencies, depths, wind speeds, and shipping distributions.

Figures 9a and b are examples of how RANDI compares with the MPL data as a function of time. Only every other point of the original MPL data (one each day) has been retained to compare with the model, since the shipping distribution near the FLIP site was reported only once each day. Figure 9a is a comparison of the MPL data and the RANDI output for 200 Hz at 560 m receiver depth. This frequency is of particular interest in checking the output of the model, since, at this frequency, both shipping and wind-wave interaction make significant contributions to the total noise level. This figure indicates that the model is, in general, within 2 or 3 dB of the measured data. The anomalous results can be explained by the presence or lack of nearby (within the same 1-deg square as FLIP) shipping which was reported (erroneously perhaps) but was not seen by FLIP personnel or could have been close to FLIP's position but not reported. The agreement at 400 Hz (Fig. 9b) is similarly encouraging for such a rough initial calibration.

Figure 9c compares the noise levels calculated for MPL by CAPT Paul Wolff (Ref. 11) using two different noise models, the noise as calculated by RANDI and the
Figure 9. RANDI model—measured data comparison for several frequencies and depths (Ref. 11).
MPL data for 100 Hz at 100 m depth. Again the agreement between RANDI and the MPL data is good.

RANDI also indicated that the noise field should have a depth dependence. The total reduction in noise level as the sensor depth increased from 100 to 3930 m was calculated to be 6 dB at 50 Hz and 4 dB at 400 Hz. The data, however, showed a reduction of about 10 and 4 dB, respectively, for the same conditions. The discrepancy at 50 Hz is largely attributable to not specifying distant (SOFAR Channel) noise sources in RANDI when the comparisons were made. This could easily add the required 4 dB, since the total SOFAR Channel “look angle” at the axis is approximately 22 deg and the nearby shipping was relatively light. A similar depth dependence was observed by Lomask and Frasetto in the Mediterranean, where they utilized the bathyscaph Trieste (Ref. 12). Weigle and Watt (Ref. 13), however, generally observed less than 3 dB depth dependence in the Mediterranean for the same frequency range. The environmental and shipping data from Ref. 13 were used as input for RANDI to enable comparison with the measured data. The results are presented in Table 1. Since the data are classified, only the differences in the measured and calculated (by RANDI) levels are given as a function of frequency and depth. It is interesting to note that although RANDI was calibrated with Pacific data, where the ambient noise levels are about 20 dB less than in the Mediterranean, RANDI calculated the Mediterranean noise within about 1 or 2 dB.

RANDI was also used to obtain the horizontal directionality of the ambient noise for one shipping distribution and wind speed during the FLIP ambient noise measurement program. The results are given in Figs. B-6 through B-11.

FUTURE IMPROVEMENTS

Improvements in the current ambient noise directionality model will be made as time and state-of-the-art permit.

Transient noise, including noise from seismic disturbances and explosions, is of considerable interest and will be included in RANDI within the immediate future.

SUMMARY

RANDI is a working FORTRAN model which calculates and plots the directional character of low-frequency ambient noise in the ocean environment. This model is conceptually simple and will be improved as time and state-of-the-art permit. It is intended to be a tool to aid in the design of noise measurement experiments and in surveillance systems design and evaluation and not for ambient noise synoptic forecasting.
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1. Navy Electronics Laboratory. Technical Memorandum 163, A Note on the Near Surface Directionality of Deep Sea Noise at 1,000 CPS, by C. N. Miller, 8 February 1956.


11. Personal communication.


13. Personal communication.
Appendix A

RANDI SUBROUTINE DESCRIPTIONS AND FLOW DIAGRAM

Figure A-1 illustrates how the main or executive routine controls the flow of logic through the 21 subroutines which comprise RANDI. This figure can also be used as a guide in "streamlining" RANDI by removing those subroutines which will not be required by the user. In such a case, "dummy" or "empty" subroutines are substituted for the originals. For example, RANDI could easily be loaded into a relatively small computer when the propagation loss versus range is to be read in and no sound-speed profile plot is required. This is accomplished by substituting "empty" subroutines for TARGET, RAPATH, SUMINT, RAYTRC, VERTEX, HSURF, SCLNCE and SSPLOT. If only a printout is desired, PLT could also be deleted.

The following is a brief functional description of each subroutine:

ALFA contains the equation for the absorption coefficient as a function of frequency and water temperature.

AUXPR calculates sea surface area intersected by a ray bundle and sums squared sound pressure when propagation loss is read in.

BIO contains equation for biological noise as a function of frequency, time and biological activity indicator.

BWIDTH integrates noise or target spectrum using an input bandwidth response function.

ERTHC corrects the sound speed profile to include the effects of earth curvature.

FUNS obtains the squared noise pressure from the shipping histogram array for a given range.

FUNU linearly interpolates between two points.

HLOSS computes absorption, spreading and refraction losses.

HSURF computes surface reflection losses.

PLT plots noise and target levels

PRINTS prints input and initial variables.
Figure A-1. RANDI subroutine flow diagram.
RAPATH generates ray paths and corresponding propagation losses.
RAYTRC determines path taken by each ray.
READIN reads input parameters.
SCLNCE produces convenient set of scale numbers for sound-speed profile plot.
SHIPIN constructs the ray for the shipping noise squared pressure versus range histogram.
SSPLOT plots sound-speed profile.
SUMINT calculates sea surface area intersected by a ray bundle and sums squared sound pressure when propagation loss not read in.
SURFI contains the squared pressure levels for thermal, shipping, wind-wave and rain noise generators.
TARGET traces rays from target to sensor and computes received signal levels and arrival angles.
VERTEX computes greatest and shallowest depths reached by ray
Appendix B

RANDI INPUT—OUTPUT
**RANDI INPUT DATA AND FORMAT**

Input data cards for RANDI include parameter cards, array cards and run-control cards.

A RANDI input parameter card consists of an arbitrary number of parameter fields in free format. Each parameter field is separated by a comma, oblique, or blank space and contains the parameter name followed by an equal sign and then the value the parameter is to be assigned for that and subsequent consecutive runs or until a new value is assigned. The array cards contain the name of the array followed by an equal sign, which is immediately followed by the first value in the array. Subsequent values are separated by a blank space. Values which are continued on additional cards are preceded by an asterisk and a blank space at the beginning of the string of values contained on the continuation card.

Data cards for consecutive runs are separated by a PAUSE run control card, which signals the end of data for one run and that further data follows for another run. The last data set is followed by an END-DATA card signaling the end of data for the last run.

The PRLOSS card precedes each array of propagation loss versus range and follows the parameter and array cards for a given run but precedes the PAUSE card. The plot data cards follow the PAUSE card at the end of that data set for a given run, since they are read directly by the plot routines and not the READIN subroutine.

Although it is possible to read in a total of thirty-six parameters and arrays, RANDI can be run, for the large majority of cases, by merely reading in a few variables. For example, if only the sound-speed profile, frequency, and sensor depth are read in, RANDI will use preprogrammed values for the other variables and arrays in calculating the ambient noise. The preprogrammed values are listed in the model input section of the model listing of Appendix C. The resulting noise calculation, then, will be for the given depth, a wind speed of 5 knots, moderately heavy shipping, an omnidirectional vertical beam response function, and a 1-Hz bandwidth centered at the input frequency integrated over a bandpass frequency response function. A 360-deg horizontal sector width, moderate bottom loss, and a latitude of 40-deg will also be used.

The following is a list and brief description of the RANDI input variables and output products.

**INPUTS**

<table>
<thead>
<tr>
<th>System</th>
<th>Name</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADANF</td>
<td>ARRAY</td>
<td>Frequency (kHz) and depth (ft) array</td>
</tr>
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<td></td>
<td>ZTG</td>
<td>FEET</td>
<td>Noise source depth</td>
</tr>
<tr>
<td></td>
<td>PHID</td>
<td>DEG</td>
<td>Declination–elevation angle</td>
</tr>
<tr>
<td>Name</td>
<td>Units</td>
<td>Description</td>
<td></td>
</tr>
<tr>
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<td>-------</td>
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<td>DELPH</td>
<td>DEG</td>
<td>Vertical half-power beamwidth</td>
<td></td>
</tr>
<tr>
<td>DGREH</td>
<td>DEG</td>
<td>Width of horizontal sector</td>
<td></td>
</tr>
<tr>
<td>BERNG</td>
<td>DEG</td>
<td>Bearing of horizontal sector</td>
<td></td>
</tr>
<tr>
<td>BNCS</td>
<td></td>
<td>Number of ray bounces</td>
<td></td>
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<tr>
<td>ABW</td>
<td>ARRAY</td>
<td>Frequency response (dB down) across bandwidth</td>
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</tr>
<tr>
<td>ARESP</td>
<td>ARRAY</td>
<td>Vertical beam response (dB down) pattern</td>
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**ENVIRONMENTAL**

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<th>Description</th>
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<tbody>
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<td>Latitude for earth curvature effects</td>
</tr>
<tr>
<td>AVELP</td>
<td>ARRAY</td>
<td>Sound-speed (ft/sec) vs depth (ft) profile</td>
</tr>
<tr>
<td>AHB</td>
<td>ARRAY</td>
<td>Bottom reflection loss (dB) vs grazing angle (deg)</td>
</tr>
<tr>
<td>APROP</td>
<td>ARRAY</td>
<td>Optional prop loss (dB) vs range (kyd) with elevation angle (deg) and ray bundle width (deg)</td>
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**NOISE SOURCES**

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<th>Units</th>
<th>Description</th>
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</thead>
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<tr>
<td>WSPD</td>
<td>KT</td>
<td>Wind speed in knots</td>
</tr>
<tr>
<td>ACTIV</td>
<td></td>
<td>Biological activity</td>
</tr>
<tr>
<td>HOUR</td>
<td>HR</td>
<td>Local time of day in hours (military)</td>
</tr>
<tr>
<td>RAIN</td>
<td>IN/HR</td>
<td>Rainfall</td>
</tr>
<tr>
<td>SHIPD</td>
<td></td>
<td>Ship density scale</td>
</tr>
<tr>
<td>ASHIP</td>
<td>ARRAY</td>
<td>Ship density (No./10000 sq mi) vs range (nmi)</td>
</tr>
<tr>
<td>SHLFR</td>
<td>NM</td>
<td>Average distance to continental shelf and surfaced sound channel</td>
</tr>
<tr>
<td>SHLFS</td>
<td></td>
<td>Number of ships within horizontal sector over continental shelf and in surfaced sound channel</td>
</tr>
</tbody>
</table>

**TARGET**

<table>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ZTG1</td>
<td>FT</td>
<td>Target depth</td>
</tr>
<tr>
<td>ZTGN0</td>
<td></td>
<td>Number of target depths</td>
</tr>
<tr>
<td>ZTING</td>
<td>FT</td>
<td>Target depth increment</td>
</tr>
<tr>
<td>RGT</td>
<td>KYD</td>
<td>Range to target</td>
</tr>
<tr>
<td>RGTNO</td>
<td></td>
<td>Number of target ranges</td>
</tr>
<tr>
<td>RGINC</td>
<td>KYD</td>
<td>Target range increment</td>
</tr>
<tr>
<td>TARG</td>
<td></td>
<td>If less than 0 TARG0 is a target line component in dB/micropascal, otherwise TARG0 is const in target spectrum level equation</td>
</tr>
<tr>
<td>TARG0</td>
<td></td>
<td>Level of line component in dB or const in spectrum equation</td>
</tr>
<tr>
<td>TARG1</td>
<td></td>
<td>Coefficient of log f</td>
</tr>
<tr>
<td>TARG2</td>
<td></td>
<td>Coefficient of (log f)²</td>
</tr>
<tr>
<td>TARG3</td>
<td></td>
<td>Coefficient of (log f)³</td>
</tr>
</tbody>
</table>
OUTPUT AND PLOT CONTROL CARDS

System
Name
OUTPT    Output data control parameter
SNPLT    Noise plot flag
HFLAG    Noise plot data card flag
SSPLT    Sound-speed profile plot flag

Three additional cards required after pause for noise plot
   Title
   Location
   Date

Two additional cards required for sound-speed plot
   Location
   Date

INPUT DATA CONTROL CARDS

HEADER    Used before a message statement
PAUSE     Used before each consecutive run except first
PRLOSS    Used before each prop loss array
END-DATA  Used at end of data or before plot cards that are at end of data

OUTPUTS

Plots
1. Noise level versus vertical arrival angle with or without target
2. Sound-speed profile

Table
Noise level versus vertical arrival angle
Target signal level versus vertical arrival angle
Total sector noise level

EXAMPLE COMPUTER RUN

An example of a typical RAND1 run follows to illustrate the input format and output products. In this example both a vertical directionality plot and a sound-speed profile
plot are requested. The input variables are sensor depth, frequency, latitude, wind speed, request for both plots, bottom loss versus grazing angle array and sound speed versus depth array. Three plot data cards are also included, giving the title, location, and date. All other parameters are automatically set equal to preprogrammed initial values.

Output

Figures B-2 through B-5 illustrate the output of RANDI for a given set of input data cards.

EXAMPLE OF HORIZONTAL DIRECTIONALITY

Shipping data for May 1, 1971, within a few hundred miles of the FLIP ambient noise measurement site, were utilized to illustrate the horizontal directionality capability of RANDI. To do this the noise field was divided into 36 horizontal pie-shaped sectors centered at the FLIP position. The vertical arrival structure of the noise field was obtained by running RANDI with different shipping distributions each time to get the average noise level every 10 deg. These levels were then reduced by 10 dB to get the per degree levels and plotted by a separate DISSPLA plot routine. Four of the 10-deg-horizontal-sector vertical directionality plots (Figs. B-8-11) have been included to demonstrate the variability in the vertical arrival structure.
Figure B.1. Example run input data cards.
Figure B-2. Typical RANDI initial parameter printout.
<table>
<thead>
<tr>
<th>D/E ANGLE (DEG)</th>
<th>NOISE LEVEL (DB)</th>
<th>D/E ANGLE (DEG)</th>
<th>NOISE LEVEL (DB)</th>
</tr>
</thead>
<tbody>
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<tr>
<td>-68.0</td>
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<td>39.0</td>
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<td>65.9</td>
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<td>-7.4</td>
<td>76.9</td>
<td>7.4</td>
<td>77.4</td>
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</table>

* DB RE MICROPASCAL**2/STERADIAN HZ

Figure B.3. Typical RANDI noise field vertical directionality printout.
EXAMPLE NOISE PLOT

LOCATION 06100N 2400W
DATE 03/23/72
WIND SPEED (KTS) 5.0
BOTTOM DEPTH (FT) 19885.0

NOISE LEVEL (DB RE 1uPa²/STR HZ)

VERTICAL RECEIVED ANGLE (DEG)

Figure B-4. Typical RANDI vertical directionality plot.
Figure B-5. Typical RANDI sound-speed profile plot.
Figure B-6. Per degree horizontal directionality of ambient noise in 10-deg sectors.
Figure 8-7. Pacific shipping data for 1 May 1971. Number of ships over 1000 gross tons per 1-deg square.
MPL DATA COMPARISON

LOCATION 2800N 12300W
DATE 05 01 71
WIND SPEED (KT) 25.0
BOTTOM DEPTH (FT) 13615.0

FREQ (HZ) 100.0
REC DEPTH (FT) 300.0
SECTOR LEVEL (DB) 71.2
HOR SEC (DEG) 10 AT 15

Figure B-8. Ambient noise vertical directionality for the 10-deg horizontal sector at 15 deg.
Figure B-9. Ambient noise vertical directionality for the 10-deg horizontal sector at 45 deg.
Figure B-10. Ambient noise vertical directionality for the 10-deg horizontal sector at 125 deg.
MPL DATA COMPARISON

<table>
<thead>
<tr>
<th>Location</th>
<th>2900m 12300m</th>
<th>Pred (Hz)</th>
<th>100.0</th>
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<tbody>
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<td>Rec Depth (ft)</td>
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<tr>
<td>Wind Speed (kt)</td>
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<td>Sector Level (dB)</td>
<td>65.6</td>
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<tr>
<td>Bottom Depth (ft)</td>
<td>13615.0</td>
<td>Hour Sec (DEG)</td>
<td>10 at 315</td>
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</tbody>
</table>

Figure B-11. Ambient noise vertical directionality for the 10-deg horizontal sector at 315 deg.
Figure B-12. Example target-ambient noise plot.
<table>
<thead>
<tr>
<th>REC ANGLE</th>
<th>TARGET LEVEL</th>
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</thead>
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<tr>
<td>13.380</td>
<td>52.29</td>
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</tbody>
</table>

58.1 DB SIG REC AT 975.0 FT FROM 150.0 DB TARGET AT 0500 KHZ, 400.0 FT DEPTH, 50.000 K YD

Figure B-13. Example target data output.
Appendix C

RESEARCH AMBIENT NOISE DIRECTIONALITY
(RANDI) MODEL LISTING
### RESEARCH AMBIENT NOISE DIRECTIONALITY (RANDI) MODEL

#### **** MODEL INPUTS ****

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<th>UNITS</th>
<th>INITIAL</th>
</tr>
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<tbody>
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<td><strong>C</strong> SYSTEM INPUTS **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADANF</td>
<td>ARRAY</td>
<td>N FREQUENCIES (KHZ) AND K DEPTHS (FT)</td>
</tr>
<tr>
<td>ZTG</td>
<td>FEET</td>
<td>NOISE SOURCE DEPTH</td>
</tr>
<tr>
<td>PHID</td>
<td>DEG</td>
<td>U/E ANGLE</td>
</tr>
<tr>
<td>DELPH</td>
<td>DEG</td>
<td>VERTICAL HALF-POWER BEAMWIDTH</td>
</tr>
<tr>
<td>DGREH</td>
<td>DEG</td>
<td>WIDTH OF HORIZONTAL SECTOR</td>
</tr>
<tr>
<td>BERNG</td>
<td>DEG</td>
<td>BEARING OF HORIZONTAL SECTOR</td>
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<td>BOUNCES ,LE. 60</td>
</tr>
<tr>
<td>ABW</td>
<td>ARRAY</td>
<td>FREQUENCY RESPONSE(DB DOWN) ACROSS FREQ IN BAND) 1 HZ BW INITIAL</td>
</tr>
<tr>
<td>ARESP</td>
<td>ARRAY</td>
<td>VERTICAL BEAM RESPONSE PATTERN OMNI ASSUMED IF NOT INPUT</td>
</tr>
<tr>
<td><strong>C</strong> ENVIRONMENTAL INPUTS **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALAT</td>
<td>DEG</td>
<td>LATITUDE FOR EARTH CURVATURE EFFECTS</td>
</tr>
<tr>
<td>AVELP</td>
<td>ARRAY</td>
<td>VELOCITY(FT/SEC) VS DEPTH(FEET) PROFILE</td>
</tr>
<tr>
<td>AMB</td>
<td>ARRAY</td>
<td>BOT-REFL LOSS(DB) VS GRAZING ANGLE(DEG)</td>
</tr>
<tr>
<td>APROP</td>
<td>ARRAY</td>
<td>OPTIONAL PROP LOSS (DB) VS RANGE (KYN) ARRAY WITH ELEVATION ANGLE (DEG) AND RAY BUNDLE WIDTH (DEG)</td>
</tr>
<tr>
<td>WSPD</td>
<td>KT</td>
<td>WIND SPEED IN KNOTS</td>
</tr>
<tr>
<td>ACTIV</td>
<td></td>
<td>BIOLOGICAL ACTIVITY SCALE 0 TO 10</td>
</tr>
<tr>
<td>HOUR</td>
<td>HR</td>
<td>TIME OF DAY IN HOURS (MILITARY)</td>
</tr>
<tr>
<td>RAIN</td>
<td>IN/HR</td>
<td>RAIN FALL</td>
</tr>
<tr>
<td>SHIPd</td>
<td></td>
<td>SHIP DENSITY SCALE 0 TO 7</td>
</tr>
</tbody>
</table>

- EQ. 0 = NO SHIPS, 7 = DENSE
- SHIPPING CALIB = MPL DATA 4/24/71
**ASHIP** ARRAY SHIP# HISTORY ARRAY - EACH BAR IS
DEFINITE 2 TO 4 NUMBERS IN THE
FOLLOWING ORDER - RANGE IN NM,
NO. SHIP PAST THAT RANGE AND
BEFORE NEXT RANGE
NEG AV SHIPS SPEED (KT) (OPTIONAL) 912
NEG AV SHIPS LENGTH (FT) (OPT) 9300
LAST DATA POINT IS LAST RANGE
**SHLFR** NM AVERAGE DISTANCE IN NAUTICAL MILES
TO THE CONTINENTAL SHELF AND
SURFACED SOUND CHANNEL WITHIN THE
SECTOR OF HORIZ ANGLE (D) (DEG)
**SHLFS** NO. SHIP WITHIN HORIZ SECTOR OVER
CONT SHELF AND IN SURFACED SOUND
CHANNEL (ATLANTIC VLAM DATA CAL)

**TARGET/THREAT INPUTS** (WHEN PROP LOSS NOT READ IN)
ZTGl FT TARGET DEPTH *LT* 0 NO TARGET
ZTENO NUMBER OF TARGET DEPTHS
ZTINC FT TARGET DEPTH INCREMENT
RGT KD RANGE TO TARGET
RGTNO NUMBER OF TARGET RANGES
RGINC KD TARGET RANGE INCREMENT
**TARG** KD TARGO IS A TARGET LINE
*LT* 0.0 TARGO IS TARGET COMPONENT IN DB/MICROPASCAL
*GE* 0.0 TARGO IS CONST IN TARGET
SPECTRUM LEVEL EQU
**TARGO** LEVEL OF LINE COMPONENT IN DB OR
CONST IN SPECTRUM EQU
**TARG1** COEFF OF ALOG10(HZ)
**TARG2** COEFF OF ALOG10(HZ)**2
**TARG3** COEFF OF ALOG10(HZ)**3

**OUTPUT AND PLOT CONTROL CARDS**
**OUTPT** OUTPUT DATA CONTROL PARAMETER
*LE* 0 NO VIRT DIR PRINT OUT - ONLY
TOTAL SECTOR LEVEL
**SNPLT** *LE* 0 NO NOISE PLOT
*GE* 0.0 REQ PLOT DATA CARDS
**HFLAG** *LE* 0 NO VELOCITY PROFILE PLOT
**SSPLT** *LE* 0 NO VELOCITY PROFILE PLOT

THREE ADDITIONAL CARDS REQUIRED AFTER PAUSE FOR NOISE PLOT
(ONLY ONE SET FOR EACH FREQ AND DEPTH LOOP)
**TYPE** FORMAT EXAMPLE DATA CARD (IN ORDER)
**TITLE** 40A1 AMBIENT NOISE DIRECTIONALITY'S NOTE (S')
**LOCATION** 13A1 4020N 01715E
**DATE** 10A1 07 22 71

TWO ADDITIONAL CARDS REQUIRED FOR SOUND SPEED PLOT
**LOCATION** 13A1 4020N 01715E
**DATE** 10A1 07 22 71
**DATA CONTROL CARDS**

HEADER
USED BEFORE A MESSAGE STATEMENT
PAUSE
USED BEFORE EACH CONSECUTIVE RUN
EXCEPT FIRST
PRLOSS
USED BEFORE EACH PROP LOSS ARRAY
END-DATA
USED AT END OF DATA OR BEFORE PLOT CARDS THAT ARE AT END OF DATA

************************************************************* BEGIN PROGRAM *******************************

DIMENSION FRE4(11),DPTH5(29),FREQ9(29)

COMMON /COMV/ ZX,ZT,G,MAXX,PHID,DELPH,BNCS,OUTPT,WSPD,GREH,SNPLT,S1PLT,ALAT,BERNH,HOUR,ACTIV,RAIN,HFLAG,ZT,GNO,ZINC,RGT,RTNO,R2GNC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS,COMA/AVELP(30)

3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADAFN(30),NUMV,NUMH

4,NUMR,NUMW,NUMBW,NUMF,COMX/CX,HBIC,ALPHAC,BION

COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
1,TOTALN=151,IST,NTST,THRL,THRD,BZ1,BZ1,W,FLAG,BANDL(11),FRE3(11)

2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASH1(30),TDB(180),TDEG(1830),KPI,TRECL,TELV,TDP,TGLRT,GT(300),WT(300),TYTLE(3),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAPS(13),CAPB(8),CAP7(8),NUMS2,FREQ,PHINC

DATA IPOZ/5HPAUSE/*IPOP/SHIPLOSS/
DATA ZT,G/20///SHLFR/900///SHLFS/0///RMAX/500///OUTPT/-1///
DATA RADCON/57.2957795///SHIPD/5.2///NUMS/9///
DATA SNPLT,SSPLT,PHID,DELPH,BNCS,OUTPT,WSPD/0,0,0,170,10,5,0/
DATA (AHB(1),I=1,10)/0,10,20,30,40,50,60,70,80,90/
DATA DGREH/1360///ALAT/40///NUMH/10///HOUR/1500///
DATA ACTIV/0///BIOS/0///RAIN/0,0/
DATA (ABW(1),I=1,4)/0,0,0,0,1,0,0,0/
DATA NUMB/4///ZT,G/-1,0///MFLAG/0,0///ZT,GNO/1,0///RTNO/1,0/
DATA (ARESP(1),I=1,4)/90,0,0,90,0,0/
DATA NUMR/4/
DATA (ASHIP(I),I=1,9)/93,1,94,154,5,215,2,92,277,2,1,337/

10 CALL READIN (IP0S)
HFLG1=HFLAG
JDPTH=0
JFREG=0

SORT FREQ AND DEPTH ARRAY INTO TWO SEPARATE ARRAYS

DO 15 KDF=1,NMF
IF (ADAFN(KDF) .LE. 2.) GO TO 11
JDPTH=JDPTH+1
DPHT5(JDPTH)=ADAFN(KDF)
GO TO 15
11 JFREG=JFREG+1
FREQ9(JFREG)=ADAFN(KDF)
15 CONTINUE
DO 160 L3=1,JDPTH
Z=DPHT5(L3)
DO 160 L4=1,JFREG
FREG=FREQ9(L4)
IF (L3+L4 .GE. 2.) HFLAG=-1.
PTEST=0.0

43
STORE FOR PRINT OUT ARRAYS THAT CHANGE

IF (VFLAG.GT.0.0) GO TO 20
DO 20 I=1,NM
AVEL1(I)=AVELP(I)

20 CONTINUE
IF (L3+L4 .EQ. 2) CALL PRINTS
JCN1=0
T0L1=0
I51=0
HOR21=1.0E-18
IF (FREQ.LT.0.1 OR. FREQ.GT.5) GO TO 170

MULTIPLE RUN CHECK
IF (VFLAG.EQ.0.0) CALL ERTHC

CALCULATE 11 BANDWIDTH FREQUENCIES
BANDW=ABW(NI,MRN-1)
FSTRT=5*(R RANDW+0.5RT(BANDW*BANDW+4.0E+6*FREQ*FREQ))
DO 30 I=1,11
A55=1
FRE4(I)=A55*BANDW*1
FRE3(I)=FSTRT+FRE4(I)
BAND1(I)=FUNU(ABW,FRE4(I),NUMBW)

30 CONTINUE

DETERMINE BIOLOGICAL SOURCE
IF (ACTIV.GT.0.0) CALL B10

CALCULATE SURFACE NOISE SOURCE INTENSITIES
CALL SURFI

ALPHAC=ALFA(40.0,FRF)
HORZ1=1.0E-18
IF (SHLF-.EQ.0.0) GOTO 32

CALCULATE INTENSITY/STERADIAN FOR HORIZ NOISE DUE TO DIST SOURCES
CALIBRATE HORIZ NOISE WITH VLM DATA (ASSUME 10 SHIPS OVER SHELF
AT 600 NM)

RDIST=SHLF-.2ND4.
SHLF=10.*ALG10(1.+SHLF)
RLOS=-6.4.1,*.ALG10(RDIST)*ALPHAC(RDIST-.001)
DO 31 J=1,11
BBI=ALG10(FRF3(J)+6.)/.25
SL1=1.5*BBI+1.16
SL2=2.3*BBI-6.274
CORL=30.

31 DBUJ=-10.-10.*ALG10(10.**SL1+10.**SL2)-RLOS+SHLF*CORL
CALL BWIDTH(HORZ1)

CONVERT TO INTENSITY/HORIZ DEG

HORZ1=HORZ1.0367777

32 CONTINUE

HORZ2=10.*ALG10(HORZ1/.109662)+84.8856

WHICH IS THE HALF ANGLE WIDTH OF SOUND CHANNEL SEEN BY RECEIVER
SOMSV IS SOUND SPEED AT NOISE GENERATOR DEPTH
CX=FUNU(ABLEP,ZX,NUMV)
PHICH=0.0
SORSV=MIN1(ABLEP(2),ABLEP(NUMV))
IF(SORSV.GE.CX) PHICH=ACOS(CX/SORSV)*RADCON

C SKIP RAYTRACE IF PROP LOSS READ IN
IF(IPOS.EQ.1POP) GO TO 175

C IF (SNPLT.LE.0.0 .AND. OUTPT.GT.0.0) PRINT 180

CS=ABLEP(2)
PHIC=0.00001

C SEARCH FOR MAXIMUM NEAR SURFACE SOUND SPEED
CM=CS
DO 40 I=1,NUMV+2
IF (ABLEP(I),GT,3000.0) GO TO 50
C=ABLEP(I+1)
IF (C.GE.CM) CM=C
40 CONTINUE
50 IF (CM.LE.CS) GO TO 60
IF (CX.LT.CM) PHIC=ACOS(CX/CM)+0.00001
60 PHISC=RADCON*PHIC

C ZBM=ABLEP(NUMV-1)
CB=ABLEP(NUMV)

C OBTAIN LIMITING ANGLE FOR BOTTOM REFLECTIONS
PHILIM=0.0
IF (CX.LT.CB) PHILIM=ACOS(CX/CB)

C INITIALIZE PARAMETERS

C PHI LOOP

CALL PRERAY (0,0,0)
IBB=0
ICZ=0

C OBTAIN INITIAL ANGLE INCREMENT
PHST=ABS(PHID)+0.5*DELPH
PHND=PHST-DELPH
PHINC=DELPH/20.0
PHI=PHST+PHINC
PHND=AMAX1(PHISC,PHND)/RADCON
70 PHI=PHI-PHINC
PHIS=PHI/RADCON
IF (PHIS.LT.PHND) GO TO 60
IF (ICZ.EQ.1) GO TO 90
IF (PHIS.GT.PHILIM) GO TO 90
IBB=1
PHIS=PHILIM+.0001
GO TO 90
80 CONTINUE
IF (ICZ.EQ.1) GO TO 100

C DRAW THROUGH IN NOISE CURVE NEAR HORIZONTAL IF PHIC.GT.0.5
C AND GET DISTANT SOURCE (HOR) NOISE COMPONENT
JCNT=JCNT+1
ISI=JP1+1
XANG(ISI1)=PHICH*7
XANG(ISI1+1)=PHICH*7
YDB(ISI1)=10.**ALOG10(10.**(THRDZ/10.)*10.**(HORDB/10.))+100.
IF(PHICH .LT. 5) YDB(ISI1)=YDB(JP1)
YDB(ISI1+1)=YDB(ISI1)
TOTLI=TOTLI+HORIZ*2.*PHICH
JP1=JP1+1

C INITIALIZE CZ FOLDING RANGE CHECK
CALL PERAY (0,0,0)
ICZ=1
IF(PHND .GT. PHILIM) GOTO 110.
PHINC=PHILIM-PHIC
IF (PHINC .LE. 0.0) GO TO 110
PHINC=1.4324*PHINC
PHIC=PHIC+0.001*RADCON
GOTO 70
90 CALL RAPATH (ICZ,PHIC,DELR)
IF (ICZ.EQ.1) GOTO 100
IF (IBB.EQ.1) GOTO 60
IF (DELR .GT. 1.) PHINC=0.5*PHINC
GOTO 70
100 CONTINUE
IF (PHIC.LT.PHILIM) GO TO 70
110 CONTINUE

C CALCULATE OMNI NOISE LEVEL
C
C IF (TOTLI .LE. 0.0) GO TO 171
TOTLN=10.0*ALOG10(TOTLI)+184.8856
HORDB=HORDB+100.
FRE1=FREQ*1000.0
PRINT 200, DEGREH,TOTLN,FRE1,ZX
CANGL=2.*PHIC
IF (SHLFS .GT. 0.0 .AND. PHIC .GE. 0.) PRINT 220,HORDB,CANGL
C BYPASS TARGET IF PROP LOSS READ IN
IF (PFSTR.EQ.1.0) GO TO 120
C
C IF (ZTGL) 120,130,130
120 IF (SNPLT .GT. 0.0) CALL PLT (PTEST)
GO TO 150
C TARGET RANGE-DEPTH LOOP
C
130 NT=2TGN0
NR=RTGNO
HTST=HFLAG
DO 140 I=1,NR
DO 140 J=1,NT
YT=J-1
YR=I-1
RTG=RTG+YR*RGINC
TGDP=ZTG1+YT*ZTINC
CALL TARGET
IF (SNPLT .GT. 0.0) CALL PLT (PTEST)
HFLAG=-1.0

140 CONTINUE
   HFLAG=HTST
150 CONTINUE
C
C PLOT SOUND SPEED PROFILE IF CALLED FOR
C IF (SSPLT GT 0.0) CALL SSPLT
C
160 CONTINUE
   HFLAG=HFLG1
   IF (IP0S .EQ. IPOZ) GO TO 10
   STOP
C
170 PRINT 210, FREQ
   GO TO 160
171 PRINT 190
   GO TO 150
C
READ PROP LOSS INSTEAD OF CALCULATING IT
175 CALL AUXPRI(IP0S,PHICH,HORZ1)
   PTEST=1.0
   GO TO 110
C
C
180 FORMAT (''/''/57X,''OUTPUT//''/''/24X,''3HPHA''/''/8X,''4HDPHA''/''/6X,''5HMAX''/''/5X,''BHLO''
   /''/6X,''SMOB UP''/''/6X,''SMOB DOWN''/''/3X,''10H1 STER COR''/''/10X)
190 FORMAT (''TOLLI ZERO OR NEGATIVE - GO TO NEXT CASE'')
200 FORMAT (''6X,F7.1'' DEG SECTOR LEVEL = ''/''F7.2'' DB FOR ''/''F6.1'' HZ''
   ''/''F7.1'' FT DEPTH''/'')
210 FORMAT (''/''/7H-FREQ ''/''/10H OUTSIDE 10-500 HZ REGION)
220 FORMAT (''/''/7H-STOP ''/''/10H VERT DEG TOTAL CHANNEL 'LOOK ANGLE'/'
   END)

FUNCTION ALFA (T,F)
C
C INPUTS
C T DEG=F TEMPERATURE
C F KHZ FREQUENCY
C
ALFA IS THE ABSORPTION COEFFICIENT
FS0=F*F
FCUBE=F*FSQ
FLOG=ALOG(F)
TC=5.0*(T-32.0)/9.0
FT=(6.0*TC+118.0)/(TC+273.0)
FT=21.9*EXP(3.3026*FT)
ALFAT=0.6542*EXP(1.5*FLOG)
FCUT=FCUBE/32.768
IF (FCUT.LT.1.0) GO TO 10
BF1=1.0/(1.0+FCUT)
BF2=1.0-BF1
GO TO 20
10 BF2=1.0/(1.0+1.0/FCUT)
BF1=1.0-BF2
20 ALFAM=FS0/FT*(0.6505317*FT/(FT*FSQ/FT)+0.026847)
   ALFA=BF1*ALFAM+BF2*ALFAM
RETURN
END
SUBROUTINE AUXPR(IPOS,PHICH,HORIZ)

THIS SUBROUTINE CALCULATES AMBIENT NOISE WHEN PROP LOSS IS READ IN AND NOT CALCULATED

COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,RNCS,OUTPT,*SPD,DGREH,SNPLT,S1SPLT,ALAT,BERNS,HOUR,ACTIV,RAIN,HFLAG,ZTG,ZTNG,2INC,TARG,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
3,ABW(30),Aresp(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
4,NUMS,NUMB,NUMF,NUM/COM/CX,ZBM,HIC,ALPHA,BION
COMM/HL/LOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WIND,1,TOTL
11,TOTLN,ISI,IST,NTST,THRML,THRBD,CD,ZBl,VFLAG,BANDL(11),FRE3(11),
2DB(11),BANDW,LOCAT(3),DATE(2),AVE1(30),ASH1(30),TOP(180),TDEG(18
30),RP1,REC,LET,TLEV,TO,RT6,9(300)+W(300),TYLE(8),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAPS(13),CAP6(13),CAP7(8),NMS2,FRE,RHINC

DATA IPOS/*PRLOS*/

. INITIALIZED PARAMETERS ARE THE FOLLOWING.

TOTL1=1.0E-18
TOTLI=TOTLI+HORIZ*2.0PHICH
JP1=0
HORDB = 10.*ALOG10(HORIZ)+84.8856
IF (PHICH .LT. .5) GO TO 1
Q(1)=-PHICH*.7
Q(2)=-Q(1)
W(1)=10.*ALOG10(10.**(THKDB/10.))+(HORDB/10.))+(100.
W(2)=W(1)
XANG(1)=1.
XANG(2)=1.
JP1=2

1 CALL READIN(IPOS)

CALCULATE WIND NOISE DIRECTIONALITY FACTOR DIRS

CX=FUNU(VELP,ZX,NUMV)
CS=FUNU(VELP,ZT,G,NUMV)
COSPH=COS(.0173*APROP(1))*CS/CX
PHI=Acos(COSPH)
EXPN=5.729*PHI
IF (PHI.LT.3.91) EXPN=2.0
DCOEF=2.*FRE=.02
IF (FRE<.6) DCOEF=1.0
DIRS=1.+(SIN(PHI)**EXPN-1.)*(DCOEF)

RI=APROP(3)
SHI=FUNS(Aship,RI,NMS2)
PRI=APROP(4)
RECTI=1.0E-18
I=1
4 ri=I+1
IF (ASH1(NS).LE.APROP(3)) GO TO 4
NP=5
SELFCT RANGE INTEGRATION INTERVAL

10 IF(APROP(NP)-ASHI1(NS))30,20,40
20 HTEST=1.0
NS=NS+2
30 HIP1=APROP(NP)
PRI1=APROP(NP+1)
SHIP1=FUNS(ASHI1,RIP1,NMS2)
NP=NP+2
GO TO 50
40 HIP1=ASHI1(NS)
PRI1=FUNS(APROP,RIP1,NUMP)
SHIP1=ASHI1(NS+1)
NS=NS+2
IF(RTEST.EQ.1.0) NP=NP+2
50 CONTINUE

C CALCULATE TOTAL SURFACE NOISE INTENSITY DENSITY FUNCTION

C = A* RANGE + B

RDIF=RIP1-RI
IF(RDIF.EQ.0.0) GO TO 80
SDIF=SHIP1-SHI
A=SDIF/RDIF
BWIND=WIND*DIRS
BSHIP=SHI-RhA
B=BWIND+BSHIP
JNI=SHI+BWIND
JNI1=SHIP1+BWIND

C CALCULATE PROP LOSS INTENSITY REDUCTION FACTOR

FROM PROP LOSS = E*RANGE + F , WHERE F INCLUDES G THE LOSS
DUE TO THE BEAM PATTERN

PDIF=PRI1-PRI
E=PDIF/RDIF
G=FUNS(ARES,APROP(1),NUMP)
F=PRI-R*E-G
IF(ABS(E) .GE. +0.001) GO TO 60
RECI=6.282*10.**(-1*F)*(-3.333*A*(RIP1**3-RI**3)+5.8*(RIP1*RIP1
1-RI*RI))
GO TO 70
60 RECEI=10. /(E**2.3025)
RECI=6.282*RECEI*(10.**(-1*PRI1)*DNIP1*(RIP1+RECEI)-10.**
1(-1*PRI1)*DN1*(RI+RECEI))
IF(ABS(A) .GE. +0.001) RECI=RECI-6.282*A*RECEI*RECEI*(10.**(-1*PRI1)
1PRI1)*(RIP1+RECEI)-10.**(-1*PRI1)*(RI+2.**RECEI))

C CALCULATE LEVEL RECEIVED FROM HORIZ SECTOR AND TEST FOR LAST RANGE

70 RECTI=RECTI+.0175*DGREH*ABS(RECI)+(THRML+BION)*APROP(2)
80 RI=RIP1

SHI=SHIP1
PRI=PRI1
IF(NP.LT.NUMP) GO TO 10

C STORE LEVEL AND ANGLE FOR OUTPUT AND GET TOTAL OMNI INTENSITY
SUBROUTINE BID

THIS SUBROUTINE COMPUTES THE CONTRIBUTION OF BIOLOGICAL NOISE

COMMON /COMVT/ ZX, ZTG, RMAX, PHID, DELPH, BNCST, OUTPT*, WSPD, DGREH, SNPLT, S1SPLT, ALAT, BERNG, HOUR, ACTIV, RAIN, HFLG, ZTG1, ZT6NO, ZTNC, RGT, RGTNO, R2GINC, TARG, TARGO, TARG1, TARG2, TARG3, SHIPD, SHLFR, SHLFS, COMA, AVELP(30), 3, AHR(30), ARES(30), ABW(30), APROP(30), ADAPF(30), NUMV, NUMH, NUMR, NUMS, NUMBF, NUMP, COMX, ZBM, PHIC, ALPHAC, BION

COMMON /ICOMV/ ZX, ZTG, RMAX, PHID, DELPH, BNCST, OUTPT*, WSPD, DGREH, SNPLT, S1SPLT, ALAT, BERNG, HOUR, ACTIV, RAIN, HFLG, ZTG1, ZT6NO, ZTNC, RGT, RGTNO, R2GINC, TARG, TARGO, TARG1, TARG2, TARG3, SHIPD, SHLFR, SHLFS, COMA, AVELP(30), 3, AHR(30), ARES(30), ABW(30), APROP(30), ADAPF(30), NUMV, NUMH, NUMR, NUMS, NUMBF, NUMP, COMX, ZBM, PHIC, ALPHAC, BION

COMMON /ICOMX/ ICX, ZBM, PHIC, ALPHAC, BION

11: TOTLN, 151, ITST, NTTST, THRL, THRDB, CO*, ZB1, VFLAG, BANDL(11), FRE3(11), 20B(11), BANDW, LOCAT(13), DATE(2), AVELL(30), ASH1(30), TDB(180), TDEG(1830), KP1, TRECL, TLEV, TGDP, RTG, Q(300), W(300), TYTLE(8), CAP1(8), CAP2(13), CAP3(13), CAP4(13), CAP5(13), CAP6(8), CAP7(8), NMS2, FRE3, PHINC
ACT=ACTIV/5.0
DO 10 J=1,11
BB1=ALOG10(FRE3(J))

B IS THE DAILY FLUCTUATION
B=.00175*(100.-FRE3(J))*SIN(.002618*(HOUR-300.))
B101=-26.6*BB1+26.
B102=26.*BB1-52.*64
10 DB(J)=-35.4-10.*ALOG10(10.**(1+B101)+10.**(1+B102))*.ACT
1+2.*ACTIV
CALL BWIDTH (92)

CONVERT TO INTENSITY/VERT DEG/HOR DEG
BION=ACT*B2*DGREH*1.5432E-5

RETURN
END

SUBROUTINE BWIDTH (DINT)
THIS SUBROUTINE INTEGRATES THE SIGNAL INTENSITY OVER BANDWIDTH
ADD BANDWIDTH RESPONSE TO NOISE SIGNAL
REAL LEVBW(11),M1=MIP1

COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNC5,OUTPT,WSPD,OGREH,SNPLT,S1SPLT,ALAT,BERG,HOUR,ACTIV,RAIN,HFLAG,ZT31,ZTN0,ZINC,RGT,R6TO,R2GNC,TARG3,TARG8,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
3,ABH(30),ARESP(30),ASHIP(30),ABW30),APROP(30),ADADF(30),NUMV,NUSH
4,NUMV,NUMB,NUMI,NUMF
COMMON HLOS(660),RING(660),XANG(300),YDB(300),JP1,JCNT,WINDI,TOT
11,TOLN=151,ITST,NTST,THRML,THDR,BD,IB1,VFLAG,BANDL(11),FRE3(11),
20B(11),BANDL,LOCAT(3),DATE(2),AVELP(30),ASHII(30),TDB(180),TDE6(18
30),KPI,TER3,TELV,TGPD,TG3(300),W(300),CAP1(8),CAP2(12),CAP3(13)
4,CAP3(13),CAP4(12),CAP5(13),CAP6(8),CAP7(8),NMS2,FREQPHINC

DINT=0.0
OBTAIN EFFECTIVE LEVELS
DO 10 I=1,11
10 LEVBW(I)=DB(I)-BANDL(I)

INTEGRATE AND CONVERT TO INTENSITIES
DO 30 I=1,10
FI=FRE3(I)
FIP1=FRE3(I+1)
MI=(LEBVW(I+1)-LEBVW(I))/(10.0*ALOG10(FIP1/FI))
BI=LEBVW(I)-ALOG10(FI)/ALOG10(FIP1/FI))*LEBVW(I+1)-LEBVW(I)
SMB=3.2467E-9*10.**(B1/10.)
IF (MI<EG-1.0) GO TO 20
MIP1=M1+1.0
DIN=(SMB/MIP1)*(FIP1**MIP1-FI**MIP1)
GO TO 30
20 DIN=SMB*ALOG1(FIP1/FI)
30 DINT=DINT*DIN
SUBROUTINE ERTHC

C THIS SUBROUTINE CORRECTS FOR EARTH CURVATURE EFFECTS

COMMON /COMV/ZX,ZTGMAX,PHII,DELPHI,BNCS,OUTP,T,SPD,DGREL,SNPLT,S
ISPLT,ALAT,BERG,HOUR,ACTIV,RAIN,HFLAG,ZTGO,ZTINC,RGT,RTGO,R
GZINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
3,ABW(30),ARESP(30),ASHIP(30),AAM(30),APROP(30),ADANF(30),NUMV,NUMH
4,NUMR,NUMB,NUMW,NUMP,COMX/CX,ZBM,PHIC,ALPHAC,BION
COMMON HLOS(660),RNG(660),XANG(300),YDB(300),JP1,JCNT,WIND1,TOTL
11,T0IUN=151,ITST1,NTST1,THMR1,THRDB1,CDZ1,VFLAG1,BAND1(11),FRE3(11),
2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG (18
30),KP1,TRECL, TLEV,TDOP,RG1,Q(300),W(300),TYTLE(8),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAP5(13),CAP6(18),CAP7(8),NMS2,FREG,PHINC

DATA RADCON/57.2957795/
DATA AB/43642464.29E7/,ASQ/43789029.00E7/,BSQ/43496390.14E7/
END

FUNCTION FUNSIA,X,N

C THIS FUNCTION INTERPOLATES THE SHIPPING HISTOGRAM

DIMENSION A(I)
ILAST=N
I=1
IF(X,GT,A(I),AND,X,LE,A(I-1)) GO TO 10
FUNS=0.0
RETURN
10 I=I+1
IF(X,LE,A(I),AND,X,GT,A(I-2)) GO TO 20
GO TO 10
20 FUNS=A(I-1)
RETURN
END
FUNCTION FUNU (A,X,N)

C DIMENSION A(I)
ILAST=N-1
I=1
IF (X.GT.A(I)) GO TO 10
FUNU=A(2)
RETURN
10 I=I+2
IF (X.LE.A(I)) GO TO 20
IF (I.LE.ILAST) GO TO 10
GO TO 30
20 IF (A(I).EQ.A(I-2)) GO TO 30
IF (X.EQ.A(I)) GO TO 30
FUNU=A(I-1)+(A(I+1)-A(I-1))/(A(I)-A(I-2))*(X-A(I-2))
RETURN
30 FUNU=A(I+1)
RETURN
END

SUBROUTINE HLOSS (PHIE,R,S,DRDP,GRAD,HKSR)
C THIS SUBROUTINE COMPUTES ABSORPTION(HK), SPREADING(HS),
C AND REFRACTION(HR) LOSSES.
C COMMON /COMX/ CX,ZBM,PHIC,ALPHAC,BION/COMCT/CV,TANPHS
C DATA FMIN/1.0E-6/FMAX/1.0E12/
IF (ABS(PHIE).LT.0.0001) GO TO 10
FOCUS=ABS(CV/CX*R*SIN(PHIE)*DRDP)
GO TO 20
10 FOCUS=ABS(CV/CX*R*TANPHS*CV/GRAD/3000.0)
20 IF (FOCUS.GT.FMIN.AND.FOCUS.LT.FMAX) GO TO 30
PRINT 40, PHIE,R,DRDP,GRAD
CALL EXIT
30 HKSR=60.0*10.0*ALOG10(FOCUS)*ALPHAC*S
C RETURN
C 40 FORMAT (5X,'PHIE,R,DRDP,GRAD',4E12.6)
END

FUNCTION HSURF (N,NP)
C THIS SUBROUTINE COMPUTES SURFACE REFLECTION LOSS
C N = NUMBER OF REFLECTIONS
C NP = PATH TYPE
C NP PATH REF'L'S
1 DU N-1
2 DD N
3 UU N
4 UD N+1
5 DP 0
6 SR 1

53
SUBROUTINE PLT (PTEST)

C THIS SUBROUTINE PLOTS THE DIRECTIONAL AMBIENT NOISE

COMMON /COMV/ ZX,ZT,G,RMAX,PHD,DEPH,BNCS,OUTPT,WSPO,DGREN,SNPLT,S
1SPLT,ALT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTNO,ZTINC,RGT,RGTM0,R
2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,H1FR,H1SF/COMX/CX,ZBM,PH
3ICON,ALPHAC,BION

COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),J1,J2,J3,WINDT,TOTL
11,TOTL1=151,ITST,NTST,THRML,THRD,CD,ZB1,VFLB0,BANDL(11),FRE3(11),
2OB(11),BANDW,LOCAT(3),DATE(2),AVE1(30),ASH1(30),TDB(180),TDEG(18
30),JPI,RECL,TLEV,TGDP,RTG,Q(300),W(300),TYTLE(8),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAP5(13),CAP6(8),CAP7(8),NMS2,FREG,PHINC

INTEGER PN

DATA BERN/270,/,PN/0/

CT:=80,0
IBR:=BERN
IDGR:=DGREN
DBMAX:=1000.

IF (HFLAG.LT.0.0 OR.HFLAG.GT.0.0 .AND.NUMF.GT.1.) GO TO 10
READ (5,160) (TYTLE(I),I=1,8)
READ (5,160) (LOCAT(I),I=1,3)
READ (5,160) (DATE(I),I=1,2)
10 CONTINUE

SET UP AND PRINT OUT HEADINGS IF REQUESTED

ENCODE (40,160,CAP1) (TYTLE(I),I=1,8)
WSPO=SPD
FREQ=FREG*1000.0
ENCODE(64,220,CAP2)(LOCAT(I),I=1,3),FRG
ENCODE(64,230,CAP3) (DATE(I),I=1,2),ZX
ENCODE(64,240,CAP4) WSPO,TOTL
ENCODE(64,250,CAP5) ZB1,IDGR,IBR
IF (OUTPT .LE. 0.) GO TO 15
PRINT 200. (CAP2(I),I=1,13)
PRINT 200. (CAP3(I),I=1,13)
PRINT 200. (CAP4(I),I=1,13)
PRINT 200, (CAP5(I),I=1,15)
PRINT 170
PRINT 180
15 CONTINUE
IF (PN.LE.0) CALL BALLPT ('PEN 2 BLACKS')
PN=PN+1
C
C SKIOP SORT IF PROP LOSS READ IN
IF (PTEST.EQ.1.0) GO TO 151
C
C SORT DATA AND SET MAX AND MIN GRAPH LIMITS
20 N=0
J=IS1-1
DO 30 I=1,J+2
N=N+1
Q(N)=XANG(I)
IF (YDB(I).LE.CD) YDB(I)=CD
30 w(N)=YDB(I)
M=0
DO 40 I=151,JP1+2
M=M+1
N=JCNT-M+1
Q(N)=XANG(I)
IF (YDB(I).LE.CD) YDB(I)=CD
IF (YDB(I).GE.CT) YDB(I)=CT
40 w(N)=YDB(I)
N=JCNT
L=J51+1
DO 50 I=L,JP1+2
N=N+1
Q(N)=XANG(I)
IF (YDB(I).LE.CD) YDB(I)=CD
IF (YDB(I).GE.CT) YDB(I)=CT
50 w(N)=YDB(I)
60 M=0
DO 70 I=2,IS1+2
M=M+1
N=JP1+1-M
Q(N)=XANG(I)
IF (YDB(I).LE.CD) YDB(I)=CD
70 w(N)=YDB(I)
C
C PRINT ANGLE AND LEVEL WHEN PROP LOSS NOT READ IN IF REQUESTED
IF (OUTPT.GT.0.) PRINT 190,G(I)*W(I)+G(JP1)*W(JP1)
C
1=1
80 SUM=0.0
90 I=I+1
IF (I.GE.JCNT) GO TO 110
SUM=SUM+ABS(Q(I)-Q(I-1))
IF (SUM.LE.0.0) 90,100,100
100 L=JP1-1+1
IF (OUTPT.GT.0.) PRINT 190,G(I)*W(I)+G(L)*W(L)
GO TO 80
110 IF (OUTPT.GT.0.) PRINT 210
CALL BGNPL (1)
CALL PHYSOR (2.0,1.5)
CALL TITLE (CAP1,-100.0,0.0,0.0,7.0,5.5)
CALL ENDEr (1)
CALL PHYSOR (2.0, 1.5)
CALL TITLE (1H =: 1, 'VERTICAL RECEIVED ANGLE ((DEG))S", 100, 'NOISE 1 LEVEL ((DB RE (MPA / STR HZ))S", 100, 7.0, 4.8)
CALL HEIGHT (1.1)
CALL ANGLE (90.0)
CALL MESSAG('25", 100, -.7, 5.2)
CALL RESET ('ANGLE')
CALL RESET ('HEIGHT')
CALL YTICKS (2)
CALL XTICKS (3)
CALL FRAME
CALL YAXANG (0.0)
CALL INTAXS
CALL MIXALF ('L/CGREEK')
CALL GRAF (-90.0, 30.0, 90.0, CD, 10.0, CT)
CALL RESET ('MIXALF')
CALL HEADIN (CAP2, 100, 1.4)
CALL HEADIN (CAP3, 100, 1.4)
CALL HEADIN (CAP4, 100, 1.4)
CALL HEADIN (CAP5, 100, 1.4)
CALL CURVE (QoW, KP1, 0)
C
C PLOT TARGET LEVELS IF CALLED FOR AND PROP LOSS NOT READ IN
C
IF (TGP0=LE.0.0.OR. PTEST.EQ.1.0) GO TO 130
KP3=3*KP1
DO 120 I=3, KP3, 3
J=I/3
Q(I-2)=TDEG(J)
Q(I-1)=TDEG(J)
Q(I)=TDEG(J)
W(I-2)=CD
W(I-1)=TDB(J)
W(I)=CD
IF (IDBMAX.LT. TDBI(J)) DBMAX=TDB(J)
IF (W(I-1).LE. CD) W(I-1)=CD
120 IF (W(I-1).GE. CT) W(I-1)=CT
IZTG1=TGP0
ENCODE(64, 260, CAP5) IZTG1=RTG
ENCODE(64, 270, CAP4) TRECL+TLEV
ENCODE(40, 280, CAP6) DBMAX
ENCODE(40, 290, CAP7)
CALL HEIGHT (1.1)
CALL MESSAG (CAP7, 100, 4.7, 4.45)
CALL HEIGHT (0.07)
CALL MESSAG (CAP4, 100, 4.3, 4.25)
CALL MESSAG (CAP5, 100, 4.4, 4.1)
CALL MESSAG (CAP6, 100, 4.4, 3.95)
CALL DASH
CALL CURVE (QoW, KP3, 0)
CALL RESET ('DASH')
CALL RESET ('HEIGHT')
130 CALL ENDPL (0)
C
C PRINT OUT ANGLE AND LEVEL WHEN PROP LOSS READ IN IF REQUESTED
C
151 I=0
56
152 I=I+1
    J=JP1+1-I
    IF (OUTPT .GT. 0.) PRINT 190, Q(J), W(J), G(I), W(I)
    IF (J=I) 154, 153, 152
153 IF (OUTPT .GT. 0.) PRINT 190, Q(J-1), W(J-1)
154 CONTINUE
    GO TO 110
C
160 FORMAT (13A5)
170 FORMAT (12X, 9HD/E ANGLE, 5X, 11HDNOISE LEVEL, 9X, 9HD/E ANGLE, 5X, 11HD
    10ISE LEVEL)
180 FORMAT (14X, 5H(DEG), 10X, 7H(DB) */ 12X, 5H(DEG), 10X, 7H(DB) */)
190 FORMAT (3X, F16.1, F14.1, F20.1, F14.1)
200 FORMAT (10X, 12AS, A2)
210 FORMAT (/7X • * DB RE MICROPASCAL * 2/STERADIAN HZ * 1/H1)
220 FORMAT (1LOCATION*, 4X, 3AS, 10X, 'FREQ (HZ) * F16, 1, 'S'*)
230 FORMAT ('DATE', 13X, 2AS, 10X, 'REC DEPTH (FT) * F11.1, 'S'*)
240 FORMAT ('WIND SPEED (KT) * F9.1, 12X, 'SECTOR LEVEL (DB) * F8.1, 'S'*)
250 FORMAT ('BOTTOM DEPTH (FT) * F8.1, 12X, 'HOR SEC (DEG) * F15, 1AT*I4, 15S*)
260 FORMAT (*** I4, * FT TARGET AT * F7.1, ** KYD $**)
270 FORMAT (F7.1, * DB REC FROM * F7.1, * DB SOURCE $**)
280 FORMAT (F7.1, * DB MAX ONE DEGREE AVERAGES $**)
290 FORMAT ('TARGET DATA $**)
END
C
SUBROUTINE PRINTS
C
THIS SUBROUTINE PRINTS THE INITIAL PARAMETERS
C
DIMENSION DOUT(24)
C
COMMON /COMV/ ZX, ZT6, RMAX, PHID, DELPH, BNCS, OUTPT, SPD, DGREH, SNPLT, S
   1SPLIT, ALAT, BERNG, HOUR, ACTIV, RAIN, HFLAG, ZTG, ZTNO, ZTINC, RGT, RGTO, R
   2GINC, TARG, TARG, TARG, TARG, TARG, TARG, TARG, SMLFR, SMLFS, COMA, AVELP(30)
   3, AHB(30), ARESP(30), ASHIP(30), AHW(30), APORP(30), ADANF(30), NUMV, NUMH
   4, NUMR, NUMW, NUMBW, NUMP, NUMF
COMMON HLOS(6, 60), RNg(6, 60), XANG(300), YDB(300), JP1, JCNT, WINDI, TOTL
   1, TOTLN, 151, ITST, NTST, THRML, THRDB, CD, ZBl, VFLAG, BANDL(11), FRE3(11),
   2B0B(11), BANDW, LOCAT(3), DATE(2), AVELI(30), ASHI1(30), TDB(180), TDEG(18
   30), KP1, TRECL, TLEVY, T6DP, RGTQ, C(300), W(300), TITLE, CAP1(8), CAP2(13)
   4, CAP3(13), CAP4(13), CAP5(13), CAP6(8), CAP7(B), NMS2, FREG, PHINC
C
DATA BLANK/5H
C
SORT SHIPPING HISTOGRAM ARRAY
C
I=-1
K=-1
1 K=K+2
    I=I+2
    IF (K .GE. NUMS) GO TO 4
    G(I) = ASHIP(K)
    G(I+1) = ASHIP(K+1)
    W(I) = 20000.
    W(I+1) = 40000.

2 IF(ASHIP(K+2) .GE. 0.0) GO TO 1
   IF(ASHIP(K+2) .LE. -50.) GO TO 3
   W(I) = -ASHIP(K+2)
   K = K + 1
   GO TO 2
3 W(I+1) = -ASHIP(K+2)
   K = K + 1
   GO TO 2
4 Q(I) = ASHIP(K)
   W(I) = 20000.
   W(I+1) = 40000.
   NUMQ = I + 1
   MAX = MAX0(NUMV, NUMR, NUMH, NUMQ, NUMBW)
   PRINT INPUT VARIABLES
   PRINT 70
   PRINT 80, FREQ, Zx, ZTg, PH1d, DELPH, BNCS, WSPD, DGREH, BERNG, HOUR, ACTIV,
   IRAIN, ALAT, SNPLT, SSPLT, HFLAG, ZTG1, ZTIC, RG1, RG2, RG3, RGT, SHIPD, SHLFR, SHLFS
   PRINT 90
   PRINT 100
   PRINT ARRAYS
   DO 60 J = 1, MAX+2
   DO 10 I = 1, 24
   10 DOUT(I) = BLANK
      IF (J .GT. NUMV) GO TO 20
      ENCODE(20, 110, DOUT(2)) AVEL1(J), AVEL1(J+1)
   20 IF (J .GT. NUMH) GO TO 30
      ENCODE(20, 110, DOUT(6)) AHB(J), AHB(J+1)
   30 IF (J .GT. NUMR) GO TO 40
   ENCODE(20, 110, DOUT(10)) ARESP(J), ARESP(J+1)
   40 IF (J .GT. NUMQ) GO TO 50
      IF (J .GE. NUMQ = 1) GO TO 44
      SUM = W(J) + W(J+1)
      IF (SUM .LT. 55000.) GO TO 41
         ENCODE(25, 130, DOUT(14)) Q(J), Q(J+1)
         GO TO 50
      41 IF (SUM .LT. 35000.) GO TO 42
         ENCODE(25, 130, DOUT(14)) Q(J), Q(J+1), W(J)
         GO TO 50
      42 IF (SUM .LT. 15000.) GO TO 43
         ENCODE(25, 140, DOUT(14)) Q(J), Q(J+1), W(J+1)
         GO TO 50
      43 ENCODE(25, 130, DOUT(14)) Q(J), Q(J+1), W(J), W(J+1)
         GO TO 50
      44 ENCODE(20, 130, DOUT(14)) Q(J)
      50 IF (J .GT. NUMBW) GO TO 60
      ENCODE(20, 110, DOUT(19)) ABW(J), ABW(J+1)
   60 PRINT 120, (DOUT(K), K = 1, 24)
   RETURN
70 FORMAT ('///48X**: ** INITIAL PARAMETERS */**/')
80 FORMAT (B8X*FREQ = F6.1, KHZ*5X*ZX = F6.1, FT*6X*ZTG = F6.1,
   1'ST*6X*PHID = F6.1, DEG*5X*DELPH = F6.1, DEG*5X*BERNG = F6.1, DEG*5X*HO
6UR = F7.2, 8X*ACTIV = F6.1, 9X*RAIN = F6.1, IN/HR*3X*ALAT = F6.1,' 
4 DEG*X*SNPLT = F6.1, 9X*SNPLT = F6.1, 8X*FLAG = F6.1, 9X*ZTG1 = F6
5.1, FT*6X*ZTNGO = F6.1, 9X*SNPLT = F6.1, 8X*FLAG = F6.1, FT*6X*RTG = F6.1,
/KYD* 6X*RTGNO = F6.1, 9X*RTGNO = F6.1, 9X*HZ = F6.1, 9X*SHF = F6.1, 
81*9X*SHLF = F6.1* FT*6X*SHLFS = F6.1/**)
90 FORMAT (11X*VEL PROFILE = 9X,'BOTTOM LOSS', 10X*BEAM RESP', 9X*SHIP
1PING HISTOGRAM = 11X* BANDWIDTH/**)
100 FORMAT (9X*FT FT*SEC, 10X*DEG*DB, 12X*DEG DB, 7X*NM
11 SHIPS KT FT*8X, FT*HZ DB DOWN/**)
110 FORMAT (F9.1, F9.1)
120 FORMAT (24A5)
130 FORMAT (F7.1, F6.1, F6.1)
140 FORMAT (F7.1, F6.1, F6.1)
END

SUBROUTINE RAPATH (ICZ, PHIS, DELR)

THIS SUBROUTINE GENERATES RAY PATHS AND CORRESPONDING
PROPAGATION LOSSES FOR BB AND CZ MODES. RAY PATH
COMBINATIONS ARE OBTAINED FOR UP TO NMAX BOTTOM
REFLECTIONS (OR REFRACTIONS) FOR EACH D/E ANGLE (PHIS).

DIMENSION SX(4), ST(4)

COMMON /COMV/ ZX, ZTG, RMAX, PHID, DELPH, BNC5, OUTPT, WSPD, DGERH, SNPLT, 
1SPLT, ALAT, BERNG, HOUR, ACTIV, RAIN, TFLAG, ZTG1, ZTNGO, ZTINC, RGTS, RGTNO, R 
2GINC, TARG, TARG0, TARG1, TARG2, TARG3, SHIPD, SHLFR, SHLFS, COMA, AVELP (30)
3, AMB (30), ARES (30), ASHIP (30), ABM (30), ADANF (30), NUMV, NUMH 
4, NUMR, NUMS, NUMBW, NUMP, NUMF, COMX, CX, ZBM, PHIC, ALPHAC, BION, COMCT/CV, T 
5ANPHS

COMMON HLOS (6, 60), RNS (6, 60), XANG (300), YDB (300), JPS, JCNT, WIND, TOL 
1, TOLN = 151, IST, NTST, THML, TTHO, CD, ZBI, VFLAG, BANL (11), FRE3 (11), 
2BB (11), BANDW, LOCAT (3), DATE (2), AVEL1 (30), ASH1 (30), TDB (10), TDEG (18 
30), KPI, TREL, TLEV, TGDP, RTG (Q (300), w (300), TYTLE (8), CAP1 (8), CAP2 (13) 
4, CAP3 (13), CAP4 (13), CAP5 (13), CAP6 (8), CAP7 (8), NMS2, FREQ, PHINC

DATA [RADCON/57.2957795/ 
DATA (SX(I)) = 1.4/1.0 = 1.0, 1.0, 1.0/ 
DATA (ST(I)) = 1.4/1.0 = 1.0, 1.0, 1.0/

C

COSPHS = COS (PHIS)
CV = CX / COSPHS
CALL VERTEX (ZLO, ZHI)
1F (ZTG > LT, ZHI OR > ZTG, GT, ZLO) GO TO 90
TANPHS = SIN (PHIS) / COSPHS
PHI = 57.296 * PHIS
C
RAYTRACE FROM SOURCE TO BOTTOM
CALL RAYRC (PHIS, ZX, ZBM, SXB, RXB, DRYX, PHIBOT, GRADB, ZEND)
BRL = FUNU (AHB, RADCON, PHIBOT, NUMH)

C
RAYTRACE FROM SOURCE UP TO SURFACE
CALL RAYRC (-PHIS, 0.0, ZX, ZSXS, RXX, DRRXS, PHIE, GRADZ, ZEND)
ZSURF=0.0
NS=0
IF (PHIE.NE.0.0) GO TO 10
IF (ZEND.NE.0.0) NS=1
ZSURF=ZEND
10 CONTINUE
IF (ZTG.EQ.ZX) GO TO 20
C
RAYTRACE FROM SURFACE (OR VERTEX DEPTH) DOWN TO TARGET
CALL RAYTRC (PHIE,ZSURF,ZTG,SST,RST,DRST,PHNO,GRADT,ZEND)
C
DIRS IS THE NOISE SOURCE DIRECTIVITY
C
EXP N=5.729*PHND
IF (PHND.LT.3491) EXPN=2.0
DIRS=1.0+(SIN(PHNO)**(EXPN-1.0)*(2.0**FREQ-.02)
IF (ZEND.EQ.ZTG) GO TO 30
WRITE (6,100) ZEND
GO TO 30
20 SST=SXS
RST=RXS
DRST=DRXS
PHND=PHIS
C
30 CONTINUE
R=2.0*RXB-RXS-RST
C
LIMIT TO FIVE BOTTOM BOUNCES
IF (ICZ.EQ.0.AND.NMAX.GT.5) NMAX=5
DO 40 N=1,NMAX
EN=N
HBOT=0.0
IF (ICZ.EQ.0) HBOT=EN*BRL
RN=2.0*EN*(RXB+RXS)
SN=2.0*EN*(SXB+SXS)
DN=2.0*EN*(DRXB+DRXS)
DO 40 K=1,4
PS=-SX(K)*PHIS
IF (PS.LT.PHMIN.OR.PS.GT.PHMAX) GO TO 40
RK=RN+SX(K)*RXS+ST(K)*RST
C
MAXIMUM RANGE CHECK
C
SK=SN+SX(K)*SXS+ST(K)*SST
DK=DN+SX(K)*DRXS+ST(K)*DRST
C
ELIMINATE CAUSTIC BY RESTRICTING DK
IF (ABS(DK).LE.1.0) DK=1.0
C
HSB=HSURF(N+K)+HBOT
CALL HLOSS (PHND,RK,SK,DK,GRADT,HK)
HK=HK+HSB*FUNU(ARESP,SX(K)*PHI,NUMR)
CALL SUMINT (K,N,NMAX,RK,HK,PHI,DIRS)
40 CONTINUE
C
C DIRECT PATH
41 K=5
S=-1.0
IF (ZX-ZTG) 50,80,60
50 PN=PHIS
   PX=PHIS
   GO TO 70
60 PN=-PHIS
   PX=-PHIS
70 RK=ABS(RXS+S•RST)
IF(PH.LT.PHMIN.OR.PN.GT.PHMAX) GOTO 80
SK=ABS(SXS+S•SST)
DK=ABS(DRXS+S•DRST)
HS=HSURF(1,K)
CALL HLOSS (PHND,RK,SK,KD,GRAD,HK)
HK=HK+HS+FUNU(AR•SP,P•N,NUMR)
CALL SUMINT (K,N,NMAX,RK,HK,PH,DIRS)
80 IF (K.EQ.6) GO TO 90
C SURFACE REFLECTED PATH
K=6
N=NMAX+2
S=1.0
PN=-PHIS
PX=PHIS
GO TO 70
C 90 CONTINUE
VELR=R-RLAST
RLAST=R
RETURN
C ENTRY PRERAY
NTST=0
ITST=1
RLAST=200,0
NMAX=BNCS
PHMA=PHID+0.5•DELPH
PHMIN=PHMAX=DELPH
IF (PHMIN.GE.0.0) ITST=2
PHMAX=PHMAX/RADCON
PHMIN=PHMIN/RADCON
RETURN
C 100 FORMAT (/5X,HZEND,E12.6//)
END
SUBROUTINE RAYTRC (PHIS,ZUP,ZLO,SP,RP,DRP,PHIEND,GRAD,ZNP1)
C PHIS POSITIVE MEANS DOWN-GOING RAY, TRACES FROM ZUP TO ZLO
C PHIS NEGATIVE MEANS UP-GOING RAY, TRACES FROM ZLO TO ZUP
C COMMON /COMA/ AVELP(30),AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(130),ADAMF(30),NUMV,NUMH,NUMR,NUMS,NUMBW,NUMF,COMCT/CV,TANPHS
C RP=0.0
SP=0.0
DRP=0.0
SINPN=SIN(PHIS)
COSP=CO5(PHIS)
PHIN=PHIS
N=1
C TEST FOR NEGATIVE PHISTART
   IF (PHIS.LT.0.0) GO TO 20
C PHIS POSITIVE, DOWN-GOING RAY
   ZN=ZUP
   10 NUM=N
       LL=1
       GO TO 40
C PHIS NEGATIVE, UP-GOING RAY
   20 ZN=ZLO
   30 NUM=NUMV-N
       LL=2
   40 AZN=AVELP(NUM)
       IF (ZN.LT.AZN) AND (LL.EQ.1) GO TO 50
       IF (ZN.GT.AZN) AND (LL.EQ.2) GO TO 50
       N=N+2
       GO TO (10,30), LL
C
C 50 ZNP1=AZN
       IF (ABS(ZNP1-ZN).LT.0.001) GO TO 150
       IF (ZNP1.GT.ZLO) ZNP1=ZLO
       IF (ZNP1.LT.ZUP) ZNP1=ZUP
       CN=FUNU(AVELP,ZN,NUMV)
       CNP1=FUNU(AVELP,ZNP1,NUMV)
C
C TEST FOR VERTEXING RAY
   IF (CNP1.GT.CV) GO TO 60
   PHINP1=ACOS(CNP1/CV)
   IF (PHIS.LT.0.0) PHINP1=-PHINP1
   COSPN1=CNP1/CV
   SINPN1=SQRT(1.0-COSPN1*COSPN1)
   IF (PHIS.LT.0.0) SINPN1=-SINPN1
   GO TO 70
C
C VERTEXING RAY COMPUTATIONS
   60 ZNP1=ZN+(CV-CN)/((CNP1-CN)*(ZNP1-ZN))
       CNP1=CV
       PHINP1=0.0
       COSPN=1.0
       COSPN1=1.0
       SINPN1=0.0
   70 DELZ=ZNP1-ZN
C
C TEST FOR VERTICAL PROFILE
   IF (ABS(CNP1-CN).GT.0.000001) GO TO 80
C VERTICAL PROFILE COMPUTATIONS
   DELRP=DELZ*COSPN/SINPN
   RP=RP+DELRP
   DELSP=DELRP*COSPN
   SP=SP+DELSP
   GO TO 90
C
C 80 GRAD=(CNP1-CN)/DELZ
   RHO=CV/GRAD
   DELRP=RHO*(SINPN1-SINPN1)
SUBROUTINE READIN (WORD)

C THIS SUBROUTINE READS THE INPUT PARAMETERS
C
INTEGER PAUSE, PARAM, HEADER, ENDTX, PRLOS, WORD, BLANK, ASTRSK, DOT, VNAME
NAME, SHLH, DATA, EQU

COMMON /COMV/ VRB(31), CUMA/ARRAY(30,7), NUMA(7), COMH/IDMR(16), COMX
I/CHIP, ZBMPHRC, ALPHAC, BION

COMMON HLSI(6,60), RN(6,60), XANG(300), YD(300), JP1, JCNT, WINDX, TOTL
I, TOLN, IP1, ITST, NTST, TNMML, THROU, CD, ZB1, VFLAG, BANDL(11), FRE3(11),
2UB(11), BANDW, LOCAT(3), DATE(2), AVEL1(30), ASH1(30), TDB(18), TDEG(18)
3D, XNP1, TREL, TLEV, TDOR, RIG1(300), W(300), TYLEL, CAP1(8), CAP2(13)
4, CAP3(13), CAP4(13), CAP5(13), CAP6(8), CAP7(8), NMS2, FREG, PHINC

C HP=RP+DELRP
DELSR=RP*(PHIN-PHIP1)
IF (DELSR,L0.0) ITEST=1
SP=SP+DELSR
C
90 CONTINUE
IF (ITEST,NE,0) WRITE (6,160) ZN,ZNP1,CN,CNP1, COSP1, COSPN1, RP, SP
C
10 CONTINUE
IF (ABS(CV=CNP1), LT, 0.00001) GO TO 120
C
C TEST FOR LAST TIME THRU FOR VERTEXING RAY
IF (ABS(PHIP), LT, 0.00001) GO TO 100

URDP=DRDP-DELRP/SINPN/SINPN1
GO TO 110
C
C TEST FOR HORIZONTAL ENTRANCE RAY.
IF ((ZNP1.EQ.ZLO) .OR. (ZNP1.EQ.ZUP)) GO TO 130
IF (PHIN), 30, 10, 10
C
C VERTEXING RAY - MUST EXIT
120 CONTINUE
URDP=DRDP+RHO/ABS(SINPN)
PHIEND=ABS(PHIP1)
140 DP=RP/3000.0
SP=SP/3000.0
URDP=DRDP/3000.0*TANPHS
C
RETURN
C
150 WRITE (6,170) ZNP1
C
RETURN
C
160 FORMAT (1X20HZN10X4HZNP18X2HCNP10X4HCOSPN18X2HCOSPN16X2HRP10X
12HSP/8E12,6)
170 FORMAT (/ZNP1=ZN=E10.4)
END
DIMENSION VNAME(31), ANAME(7), DATA(5), IDATA(16), JDATA(81)
DATA (VNAME(I),I=1,31)/5HZX, 5HZTG, 5HRMAX, 5HPHI, 5HDELPH, 5HB
1NC5, 5HOUTPT, 5HSWPD, 5HGREG, 5HSNPLT, 5HSPLT, 5HALAT, 5HERNG, 5HOU
2R, 5HACTIV, 5HRAIN, 5HFLAG, 5HSIG1, 5H2TGN0, 5H2TINC, 5HRGT, 5HRGTO
3, 5HSGINC, 5HTARG, 5HTARG0, 5HTARG1, 5HTARG2, 5HTARG3, 5HSHIPD, 5HSHLF,
4, 5HSHLF5/
DATA NV/31/ DATA (ANAME(I),I=1,7)/SHAELP, SHAHB, SHARESP, SHASHIP, SHABW, SHAP
1ROP, 5SHADNF/
DATA NA/7/ DATA PAUSE, PARAM, HEADER, ENDATA, PRL05, BLANK, ASTRSK, DOT, 'PA
1RAM', 'HEAD', 'END', 'PRL05', '!', '*', 'E' /
DATA KOMA/1/, KOUT/2/ DATA KINN/1/, KOUT/2/
IF IWORD, NE, PRLOSI WRITE (6, 230)
C READ AND PRINT INPUT CARU
10 READ (5, 240) KINN(I), IDATA(I), I=1,16 WRITE (6, 240) KOUT(I), IDATA(I), I=1,16
K=1 DECODE(80, 250, IDATA) (JDATA(J), J=1,80)
C SEARCH FOR BEGINING OF LABEL
20 DO 30 J=K, 80
IF JDATA(J), EQ, KOMAJ, JDATA(J)=BLANK
IF JDATA(J), EQ, SLSHJ, JDATA(J)=BLANK
30 CONTINUE
GO TO 10
C FIND THE END OF THE LABEL
40 DO 50 K=J, 80
IF JDATA(K), EQ, EGUJ, GO TO 60
IF JDATA(K), EQ, BLANK, GO TO 60
IF JDATA(K), EQ, KOMAJ, GO TO 60
IF JDATA(K), EQ, SLSHJ, GO TO 60
50 CONTINUE
GO TO 80
C PACK UP TO FIVE CHARACTERS OF LABEL INTO CONTROL WORD
60 K=K
JDATA(K)=BLANK IF (K-J, GE, 5), K5=K+4
DATA (I)=BLANK ENCODE(10, 250, IDATA) (JDATA(J), J=J, K5)
WORD=DATA(I)
IF WORD, EQ, PAUSE, OR, WORD, EQ, ENDATA, OR, WORD, EQ, PRL05, RETURN
IF WORD, EQ, HEADFR, GO TO 210
IF WORD, EQ, PARAM, GO TO 20
IF WORD, EQ, ASTRSK, GO TO 200
C SEE IF LABEL IS A PARAM OR ARRAY
70 IF I=1, NV GO TO 90 IF (I, GT, NA), GO TO 70 IF WORD, EQ, ANAME(I), GO TO 180
70 CONTINUE
C MUST BE AN ERROR
   80 WRITE (6,260) WORD
   GO TO 220
C
C     SET UP TO PROCESS SINGLE VALUED PARAMETER
   90 ASSIGN 170 TO JAD
       KIND=1
C
C     PUT VALUE STRING TOGETHER
   100 DO 110 J=K*80
   IF (JDAT(A(J)).EQ.BLANK) GO TO 120
   110 CONTINUE
   120 GO 130 K=J*80
   IF (JDAT(A(K)).EQ.KOMA) GO TO 20
   IF (JDAT(A(K)).EQ.SLISH) GO TO 20
   IF (JDAT(A(K)).EQ.EQU) JDAT(A(K))=BLANK
   IF (JDAT(A(K)).NE.BLANK) GO TO 140
   130 CONTINUE
       VAL=0.0
   GO TO 10
   140 NDOT=0
   DO 150 J=K*80
   IF (JDAT(A(J)).EQ.BLANK) GO TO 160
   IF (JDAT(A(J)).EQ.DOT) NDOT=NDOT+1
   IF (JDAT(A(J)).EQ.KOMA) GO TO 160
   IF (JDAT(A(J)).EQ.SLISH) GO TO 160
   150 CONTINUE
       J=81
   160 KAR=JDAT(A(J))
       JDAT(A(J))=BLANK
C
C     INSERT A DECIMAL POINT IF NUMBER HAD NONE
   IF (NDOT.EQ.0) JDAT(A(J))=DOT
   DATA (1)=BLANK
   DATA (2)=BLANK
   ENCODE(10,250,DATA)(JDAT(A(JX),JX=K,J)
       JDAT(A(J))=KAR
C
C     FORM THE VALUE AS A REAL
   DECODE (10*270,DATA) VAL
   K=J
C
C     GO TO STORE PARAMETER OR ARRAY ELEMENT
   GO TO JAD, (170*190)
C
C     STORE SINGLE VALUE IN THE RIGHT SPOT AND GO BACK FOR MORE IF CARD N
   170 VRBL(I)=VAL
   IF (K.GE.80) GO TO 10
   GO TO 20
C
C     SET UP TO PROCESS ARRAY ELEMENTS
   180 ASSIGN 190 TO JAD
C
C     VFLAG IS THE VELOCITY PROFILE RERUN FLAG FOR CURVATURE
   IF (I.EQ.1) VFLAG=0.0
       KIND=2
       NX=0
   GO TO 100
UPDATE NUMBER OF ELEMENTS FOR THIS ARRAY AND STORE THE VALUE

\[ \text{NX} = \text{NX} + 1 \]

\[ \text{ARRAY}(\text{NX}, \text{I}) = \text{VAL} \]

\[ \text{NUMA}(\text{I}) = \text{NX} \]

\[ \text{IF } (\text{K}, \text{GE}, 80) \text{ GO TO 10} \]

\[ \text{IF } (\text{JDATA}(\text{K}), \text{EQ}, \text{BLANK}) \text{ GO TO 100} \]

\[ \text{GO TO 20} \]

\[ \text{IF } (\text{KIND}, \text{EQ}, 2) \text{ GO TO 100} \]

\[ \text{GO TO 80} \]

READ AND STORE THE TITLE INTO THE COMMON AREA

\[ \text{READ (5,240) KIND, (HDR(IX)), IX=1,16) WRITE (6,240) KOUT, (HDR(IX)), IX=1,16) \]

GO TO 10

CALL EXIT

SUBROUTINE SCALE (TMIN, TMAX, ND, SNMIN, SNMAX, SNINC)

THIS SUBROUTINE PRODUCES A NICE SET OF SCALE NUMBERS FOR A PLOT AX

INPUTS ARE THE DATA MIN 'TMIN', DATA MAX 'TMAX', AND THE REQUIRED N

INTERVALS ALONG THE AXIS 'ND'. THE ROUTINE OUTPUTS A NEW MIN 'SNMI

MAX 'SNMAX', AND INCREMENT 'SNINC' FOR ND+1 READABLE VALUES

DIMENSION POWTEN(7), TICVAL(8)

DATA (POWTEN(I), I=1,7)/10., 100., 1000., 10000., 100000., 1000000., 10000000./

ALLOWABLE VALUES ARE SOME 'TICVAL' TIMES SOME POWER OF TEN

DATA (TICVAL(I), I=1,8)/0.5, 1.0, 1.5, 2.0, 5.0, 10., 15., 20./

DIV = ND

SET UP ROUNDING VALUE

ROUND=0.01

ST=TMIN

IF (ST.LT.0.0) ROUND=ROUND-1.0

DETERMINE FIRST GUESS AT INCREMENT

\[ P = (\text{TMAX} - \text{TMIN}) / \text{DIV} \]

\[ \text{IF } (\text{D}, \text{LT}, 10.0) \text{ GO TO 30} \]

REDUCE INCREMENT TO RANGE (1 - 10)

\[ \text{DO 10 } \text{I}=2,7 \]

\[ \text{IF } (\text{POWTEN(I)}, \text{GT}, D) \text{ GO TO 20} \]

CONTINUE

\[ \text{P}=\text{POWTEN(I)-1} \]

\[ \text{D}=\text{D}/\text{P}-0.01 \]

66
C FIND FIRST ALLOWABLE TICVAL
00 40 I=1,7
   IS=I
   IF (TICVAL(I)*GE.0) GO TO 50
40 CONTINUE
C COMPUTE NEW INCREMENT
50 D=TICVAL(IS)*P
   ST=D*INT(ST*D+ROUND)
C TEST NEW INCREMENT TO MAKE SURE DATA WILL FIT IN NEW RANGE
   TEST=ST+(DIV*0.01)*D
   IF (TEST*GE.TMAX) GO TO 60
      IS=IS+1
      GO TO 50
C COMPUTE NEW MIN AND ADJUST
60 ST=ST-AINT((DIV+(ST-TMAX)/D)/2.0)*D
   IF (ST*LE.TMIN) 70,70,80
50 SNMIN=ST
C COMPUTE NEW MAX
   SNMAX=ST+DIV
   SNINC=D
   RETURN
END

SUBROUTINE SHIPN (SHIPN)

THIS SUBROUTINE CONSTRUCTS THE SHIPPING DENSITY NOISE INTENSITY
HISTOGRAM

COMMON /COMV/ ZX,ZT,G,RMAX,PHID,DELP,GNST,OUTP,SPD,DGREG,SNLN,ST
ISPL,T,A,BERNO,HOUR,ACTIV,RAIN,T,FLAG,ZT,G,ROZT,RTG,RTGNO,R
2GINC,TARG,TARG,TARG,TARG,SHIPD,SHLFR,SHLF,COMA/AVELP(30)
3,AMBI(30),ARESP(30),ASHIP(30),ABW(30),APR(OP(30),ADANF(30),NUMV,NUMH
4,NUMS,NUMB,NUMP,NUMF
COMMON /COM/16060,RNG,660,XANG,300,40J,JCNT,T,WIND,TOTL
11,TOTLN,151,1ST,NTST,THRML,THRD,CD,ZB1,VLnP,BANDL(11),FRE3(11),
20B(11),BANDW,LOCAT,DATE,2AVE(1),ASHI(30),TDH(180),TDEG(18
30),KPI,TRCL,TEV,TGDP,RTG,G(300),W(300),YTL(8),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAP5(13),CAP6(8),CAP7(8),NMS2,FREG,PHINC

C REAL LMULT
C
J=0
K=NUMS-2

DO 40 I=1,K+2
C INITIALIZE PARAMETERS
LMULT=1.0
SMULT=1.0

67
STORE SHIPS AND FIRST RANGE OF RANGE INCREMENT

RANG1=ASHIP(I)
SHIPS=ASHIP(I+1)
J=J+2
10 IF (ASHIP(I+2) .GE. 0.0) GO TO 30

CALCULATE INTENSITY MULTIPLICATION FACTORS FOR SHIP SPEED AND LENGTH

IF (ASHIP(I+2) .LE. -50.0) GO TO 20
ADSHP=ASHIP(I+2)/12.0
SMULT=2.0**(ADSHP/3.0103)
I=I+1
GO TO 10

20 ADLNG=ASHIP(I+2)/300.0
LMULT=2.0**(ADLNG/3.0103)
I=I+1
GO TO 10

CALCULATE AREA AND CONSTRUCT SHIPPING DENSITY NOISE INTENSITY HISTOGRAM

RANG2=ASHIP(I+2)
AREA=0.007266*(RANG2**2-RANG1**2)*DGREH
DENS=SHIPS*10000./AREA
ASHI1(J-1)=RANG1*2.*ASHI1(J)=DENS*SHPI*SMULT*LMULT
40 CONTINUE

NMS2=J+1
ASHI1(J+1)=RANG2*2.*
RETURN

END

SUBROUTINE SSPLT

THIS SUBROUTINE WILL PRODUCE A CALCOMP PLOT OF A SOUND SPEED PROFILE. THE DEPTH VALUES ARE ALONG THE X AXIS AND THE VELOCITY VALUE IS ALONG THE Y AXIS. THE PLOT WILL BE DRAWN ON A 8.5 X 11 INCH PAGE WITH AN

DIMENSION LABEL(14), X(15), Y(15)
COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,FLAG,RTG,RGTNO,R
2GNC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS,COMA/AVELP(30)
3,ASHI1(30),ARESP(30),ASHI1(30),SHIPI(30),APROPI(30),ADAF(30),NUMV,NUMH
4,NUMR,NUMF,NUMBW,NUMPR,NUMF
COMMON HRNO(6*60),RANG(6*60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
1*TOTLN,IS1*IST,NTST,THRLML,THRDB,CD,ZB1,VFLAG,BAND0(11),FRE3(11),
2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TEDG(1A
30),KPI,TRECL,TEL,TDGP,RTG,Q(300),W(300),TYTLE(8),CAP1(8),CAP2(13)
4,CAP3(13),CAP4(13),CAP5(13),CAP6(8),CAP7(8),NMS2,FREQ,PHINC
DATA NP/100/
C
NP=NP+1
NV=NUMV/2
BEGIN PLOT
CALL BGNOPL (NP)
IF (HFLAG, LS, 0, 0, OR, SNPLT, G0, 0) GO TO 10
READ (5, 50) (LOCAT(I), I=1, 3)
READ (5, 50) (DATE(I), I=1, 2)
10 CONTINUE
ENCOD(40, 70, CAP2) (LOCAT(I), I=1, 3)
ENCOD(40, 80, CAP3) (DATE(I), I=1, 2)
CALL TITLE (1H,, 1-0, 0, 0, 0, 5, 0, 3, 0)

FIND RANGE OF SOUN D S PEE D
YMIN=60000.0
YMAX=0.0
DO 20 I=1, NV
X(I)=AVEL1(I, 2*I-1)
Y(I)=AVEL1(2*I)
IF (Y(I), GT, YMAX) YMAX=Y(I)
IF (Y(I), LT, YMIN) YMIN=Y(I)
20 CONTINUE

FIGURE OUT NICE SCALES FOR X AND Y
CALL SCLNCE (YMIN, YMAX, 5, YMN, YMX, YINC)
CALL SCLNCE (X(1), X(NV), 10, XMIN, XMAX, XINC)

SET UP AND DRAW THE X AND Y AXIES
CALL BANGLE (180, 0)
CALL BSHIFT (4, 5, 3.0)
CALL GRAF (XMIN, XINC, XMAX, YMN, YINC, YMX)

SET UP THE REQUIRED ALPHABET
CALL BASALF ('L/CSTD')
CALL MIXALF ('STANDARD')
CALL HEIGHT (0, 1)

CALL CURVE (X, Y, NV, 0)

MAKE AND LABEL X AXIS
XTMP=XMIN
DO 30 I=1, 11
IXTM=XTMP
ENCOD (10, 60, LABEL(13)) IXTM
LABEL(I)=LABEL(14)
30 XTMP=XTMP+XINC
CALL XAXANG (90, 0)
CALL XBAXS (LABEL, 1, 11, 5, 0, 5', 100, 0, 0, 0, 0)

MAKE AND LABEL Y AXIS
YTMP=YMN
DO 40 I=1, 6
IYTMP=YTMP
ENCOD (10, 60, LABEL(13)) IYTMP
LABEL(I)=LABEL(14)
40 YTMP=YTMP+YINC
CALL YLBAXS (LABEL, 1, 6, 3, 0, 'SOUND S PEE D - FT/SEC', 100, 0, 0, 0, 0)
CALL ANGLE (-180, 0)
CALL MESSAG ('DEPTH - FEET', 15, 3, 0, 0, 6)
CALL ANGLE (90, 0)
CALL RESET ('BASALF')
CALL MESSAG (CAP2, 100, 0, 1.25, 45)
CALL MESSAG (CAP3, 100, 0, 1.0, 45)
C FRAME AND END PLOT
CALL FRAME
CALL ENDPLOT (0)
RETURN
C
50 FORMAT (3A5)
60 FORMAT (110)
70 FORMAT (2LOCATIONS,4X,3A5,' ',$)
80 FORMAT (*DATE*,13X,2A5,' ',S)
END

SUBROUTINE SUMINT (K,N,NMAX,RK,HK,PHI,DIRS)
THIS SUBROUTINE COMPUTES THE NOISE INTENSITY ALONG EACH RAY
C
COMMON /COMV/, ZX, ZT, RMAX, PHID, DELPH, BNCS, OUTPT, SPD, DGREH, SNPLT, S
1PLT, ALAT, BEING, HOUR, ACTIV, RAIN, HTZG, ZTNZ, RART, RGTNO, R
2G, RARTO, RARTA, RARTG, SHIPD, SHPL, SHLS, COMA, AVELP (30)
3, AHER (30), AREP (30), ASHIP (30), ABW (30), APROP (30), ADNAP (30), NUMV, NUMH
4, NUMA, NUMB, NUMW, NUMV, NUMP/COMX/CX, ZBM, PHIC, ALPHAC/BION
COMMON HL0S (4, 60), RING (4, 60), XANG (300), YD3 (300), JPI, JNT, WINI, TOTL
11, TOTL, 151, ITST, ITST, THML, THRD, CD, 2B1, VFLAG, BANDL (11), FRE (11),
20B (11), BANDW, LOCAT (13), DATE (2), AVEL (30), ASHII (30), TDEG (18)
30, KP1, KRECL, TLEV, TDOP, RTG, (300), W (300), TYTEL (8), CAP1 (8), CAP2 (13)
4, CAP3 (13), CAP4 (13), CAP5 (13), CAP6 (8), CAP7 (8), NMS2, FREQ, PHINC
C DATA RADCN/57.2957795/
TEST FOR FIRST BOUNCE
IF (NTST.EQ.1) GO TO 10
NTST=1
DOWN=0.0

UPI=0.0
10 ABSFI=ABS(PHINC)
R6=RK
C
SHIP1=FS(ASSH1, RG, NMS2)
DR=ABS(RNG(K,N)-RK)
IF (RK.EQ.0.0.OR, RNG(K,N).EQ.0.0) DR=5.0
HL=.5*(HK+HL0S(K,N))
HL0S(K,N)=HK
RNG(K,N)=RK
C TEST FOR FIRST TIME THRU
IF (ITST.EQ.1.AND, K.EQ.6) GO TO 70
IF (ITST.EQ.2 .AND, K.EQ.2 .AND, N .EQ. NMAX) GO TO 70
IF (ITST.GE.1) GO TO 50
AREA=DGREH*0.00873*DR*(2.0*RG+DR)
AXZ=AREA*0.5*HL/3.0103
C ASSUME WIND NOISE DIPOLE DIRECTIONALITY PATTERN AT HIGH FREQ
70
C
RECI=XZ*WINDI*DIRS
SREC=XZ*SHIP1
TOTI=RECI+SREC
IF (K,GE,3) GO TO 20
DOWNI=DOWNI+TOTI
GO TO 30
20 UPI=UPI+TOTI
PHUP=-PHI
30 CONTINUE
IF (K,NE,2,AND,ITST,EQ,-1,AND,N,NE,NMAX) GO TO 31
IF (K,NE,6) GO TO 50
31 CONTINUE
NTST=0
DOWNI=DOWNI+(THRML+BION)*ABSFI
UPI=UPI+(THRML+BION)*ABSFI
TOTLI=TOTLI+DOWNI+UPI
DBDN=10.0*ALOG10(DOWNI)+18.4,8856
DBUP=10.0*ALOG10(UPI)+18.4,8856
C NORMALIZE LEVEL TO ONE STERAD AND STORE ARRAYS FOR NOISE PLOT
C JCNT=JCNT+1
C CALCULATE PER STERADIAN CORRECTION FACTOR
ADDB=10.0*ALOG10(ABSFI*COS(PHI/RADCON)*1.09662)
J=2*JCNT-1
JP1=J+1
XANG(J)=PHUP
YDB(J)=DBUP+ADDB
XANG(JP1)=PHI
YDB(JP1)=DBDN+ADDB
40 CONTINUE
IF (SNPLT,GT,0.0,OR,OUTPT,LE,0.0) GO TO 50
PRINT 90,PHI,PHINC,RNG(4,NMAX),HLOS(4,NMAX),DBUP,DBDN,ADDB
50 RETURN
C 70 ITST=0
IF (K,NE,2) ITST=-1
RETURN
C
90 FORMAT (16X,8F12.3)
END
SUBROUTINE SURFI
C THIS SUBROUTINE CALCULATES THE INTENSITIES OF ALL THE SURFACE
NOISE GENERATORS
C COMMON /COMV/ ZX, ZT, RMAX, PHID, DELPH, RNC5, OUTPT, WSPD, D6REH, SNPLT, S
1SPLIT, ALAT, BERG, HOUR, ACTIV, RAIN, HFLAG, ZT61, ZT62, ZT63, RGT, RGTNO, R
2GNC, TARG, TARGO, TARG1, TARG2, TARG3, SHIP, SHLFR, SHLFS, COMA, AVELP(30)
3, AHB(30), ARESP(30), ASHIP(30), ABW(30), APROP(30), ADANF(30), NUMV, NUMH
4, NUMV, NUMH, NUMB, NUMF, COMX/CX, ZBM, PHIC, ALPHAC, BION
C
COMMON HLOS(6,60), RNG(6,60), XANG(300), YDB(300), JP1, JCNT, WINDI, TOTL
I, TOTLI, JST, NTST, THRML, THROB, CDZB1, VFLAG, BANDL(11), FRE3(11),
2DB(11), BANDW, LOCAT(3), DATE(2), AVEL1(30), ASHII(30), TDB(180), TDEG(18
30), XPI, TREC, TLEV, TGDP, RTG, Q(300),W(300), TYTLE(8), CAP1(8), CAP2(13)
4, CAP3(13), CAP4(13), CAP5(13), CAP6(8), CAP7(8), NMS2, FREG, PHINC
WINT, RAINI AND ASHIP(2N) ARE SOUND INTENSITY DENSITIES DUE TO WIND, RAIN AND SHIPS. (WATTS/M**2)/Kyd**2

DO 10 J=1,11
   BB1=ALOG10(FRE3(J))
10   DB(J)=BB1*(4.22*BB1-33.4)-10.9
   CALL BWIDTH (THRML)

ESTABLISH LOWEST THERMAL LEVEL/VERT DEG/HOR DEG

   THRML=THRML*DGREH*1.5432E-5
   THRDB=10.0*ALOG10(THRML+BION)+84.8856

ESTABLISH MINIMUM SCALE CD FOR NOISE PLOT
AND CONVERT TO DB/MICROPASCALS

   CD=20.0
   IF (THRDB.LE.-80.0) CD=10.0
   IF (THRDB.LE.-90.0) CD=0.0
   IF (THRDB.LE.-100.0) CD=-10.0
   IF (THRDB.LE.-110.0) CD=-20.0

WINT=0.0
   IF (WSPD.EQ.0.0) GO TO 30

WMULT IS WIND SPEED DEPENDENCE

   WMULT=.065*WSPD**.7
   DO 20 J=1,11
      BB1=ALOG10(FRE3(J))
   20   CORW=29.6*10**+1.03E-5*FRE3(J)**1.54
        WLEV1=-18.8*BB1-4.9
        WLEV2=9.66*BB1*BB1-8.99*BB1+23.33
    DB(J)=WLEV1+(WLEV2-WLEV1)*WMULT+CORW
    CALL BWIDTH (WINT)

30 RAINI=0.0
   IF (RAIN.EQ.0.0) GO TO 50

CALCULATE NOISE DUE TO RAIN

   ARAIN=ALOG10(RAIN)
   DO 40 J=1,11
      BB1=ALOG10(FRE3(J))
   40   DB(J)=CORW+5.5*BB1+14.5*ARAIN-9.5
    CALL BWIDTH (RAINI)

50 WIND=WINT+RAINI

CORL IS THE MODEL DISTORTION FACTOR FOR OMNI SOURCES

   IF (SHIPD.EQ.0.0) GO TO 90
   DO 60 J=1,11
      BB1=ALOG10(FRE3(J)-2.*SHIPD+12.)
   60   CORL=14.*FREQ+8.74+4.*SHIPD
       SL1=-1.0*BB1+1.16
SUBROUTINE TARGET

C THIS SUBROUTINE COMPUTES THE DIRECTIONAL SIGNAL
C LEVEL RECEIVED FROM A TARGET

C COMMON /CONV/ ZX,ZT6,RMAX,PH1D,DELPH,BNC5,OUTPT,WSPD,DGREH,SNPLT,S
1SPLIT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTNGO,ZTIN0,RTG,RGTNC,R
2GNC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHFR,SHLFS/CONMA/AVELP(30)
3,ABW(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
4,NUMP,NUMB,NUMP,NUMF/COMA/CX,AVELP(30),ARESP(30),ASHIP(30),ABW(30)
5,APROP(30),ADANF(30),NUMV,NUMH
6,SHIPI:0,SHIPI:0
70 CONTINUE
80 CONTINUE
90 SHIPI:0,GO TO 70
END

DO 10 J=1,11
10 DB(J)=TARG0+TARG1*B01+TARG2*B01**2+TARG3*B01**3
CALL BWIDTH (TRGTI)
GO TO 30
20 TRGTI=3.2467E-9*10.**((TAKG0/10.))
30 CONTINUE

C TLEV IS EFFECTIVE TARGET LEVEL IN DB
C TLEV=10.*ALOG10(TRGTI)*84.8856
C
C FIND BOTTOM GRAZING ANGLE
PHIBM=ACOS(CX/AVELP(NUMV))

40 PHI1=DELPH/(2.*RADCON)
   IF (RGTGE.500.) GO TO 200
   CZ=-1.0
   TEST=0
   DPHI=-.05
   TINT1=1.0E-35
50 IR=0
   XTRAB=0.0
   
C TEST FOR RAY WITHIN ACCEPTABLE ANGULAR LIMITS
C
   IF (PHIH.GT.PHIBM.AND.CZ.GT.0.0) GO TO 180
   IF (PHIH.LT.0.0) OR (PHIH.LT.PHIBM.AND.CZ.LT.0.0) GO TO 200
   COSP1=COS(PHI1)
   CV=CX/COSP1
   CALL VERTEX (ZLO,ZHI)
   
C TEST FOR RAY UNABLE TO REACH TARGET DEPTH
C
   IF (ZLO.LT.(TGDPS5.0).OR.ZHI.GT.(TGDPS5.0)) GO TO 160
   TANPHS=TAN(PHI1)
   CALL RAYTRC (-PHIH,0.0,ZX,S1,R1,DRDP1,PHND1,GRAD1,ZEND1)
   CALL RAYTRC (PHND1,ZEND1,TGDPS2,R2,DRDP2,PHND2,GRAD2,ZEND2)
   CALL RAYTRC (PHIH,ZX,ZBM,S3,R3,DRDP3,PHND3,GRAD3,ZEND3)
   
C TEST FOR RELATIVE POSITION OF TARGET
C
   IF (TGDPSZ) 60,60,70

C TARGET ABOVE RECEIVER
60 RG1=2.*R2
   RG2=2.0*(R3+R1-R2)
   RSUP=R1-R2
   RSDN=R1-R2+2.*R3
   E1=1.0
   E2=0.0
   GO TO 80
C TARGET BELOW RECEIVER
70 RG1=2.0*(R3+R1-R2)
   RG2=2.0*R2
   RSUP=R1+R2
   RSDN=R2-R1
   E1=0.0
   E2=1.0

C TEST FOR UP-GOING OR DOWN-GOING RAY
80 IF (UP) 90,90,100
C

90 RSTRT=RSON
F1=1.0
F2=0.0
GO TO 110
C

UP GOING RAY

100 RSTRT=RSUP
F1=0.0
F2=1.0
110 SIZE=RG1+RG2
C
C
CALCULATE NUMBER OF CYCLES TO TARGET
C
IF (TEST.EQ.0) N=(RTG-RSTRT)/SIZE
YDN
RNODE=Y0*SIZE+RSTRT
TEST=1
C
C
TEST TO GET THE SAME NODE AS FIRST TIME THRU AND LOCATION OF
TARGET IN CYCLE
C
IF (IR) 130,120,140
120 IF (RNODE+RG1-RTG) 130,130,140
130 RNODE=RN0DE+RG1
G1=1.0
IR=1
GO TO 150
140 RNODE=RN0DE
G1=0.0
IR=1
150 CONTINUE
C
C
TEST FOR RAY WITHIN RANGE INCREMENT
C
DR2=RN0DE-RTG
IF (DR2) 160,170,170
160 PHI1=PHI1+DPHI*(1.0+PHI1*13*(1.0+CZ))
GO TO 50
C
C
CALCULATE LOSSES
C
170 CONTINUE
C
TEST FOR BOTTOM BOUNCE
C
BLOS=0.0
SLOS=0.0
IF (ZEND3.GE.ZBM) BLOS=FUNU(AHB,PHND3,RADCON,NUMH)
IF (ZEND1.LE.0.0) SLOS=Y0*5
IF (UP.LE.0.0.AND.TGDP.LE.ZX.OR.TGDP.GE.ZX.AND.G1.EQ.1.0) XTRAB=1.10
PHI=UP*PHI1*RADCON
TLOS=(Y0*XTRAB)*BLOS+HLOS1+FUNU(ARESP PHI,NUMR)
SUM INTENSITY OVER ONE DEGREE AND STORE

KP1=KP1+1
TDB(KP1)=TLEV-TLoS=SLOS
TDEG(KP1)=PHI
TGIN(T=10.*TDB(KP1)/10.*)
TINT1=TINT1+TGIN
TREC1=TREC1+TGIN
IF (ABS(TDEG(KP1)-TDEG(KP1-1))<LT.110) GO TO 210
IF (Y0.NE.YLAST AND Y0.GT.5.) TINT1=2.*TINT1
TDB(KP1)=10.*ALOG10(TINT1)
PRINT 240, TDEG(KP1),TDB(KP1)
TINT1=1.0E-35
IF (RNOD1.EQ.RSTRT) GO TO 180

TEST FOR CHANGE FROM UP TO DOWN GOING RAYS

IF (PHI1.GT.PHIB) AND (CZ.LT.0.0) OR (PHI1.LT.PHIB) AND (CZ.GT.0.0) GO 1 TO 110
IF (CZ.GT.0.0) GO TO 180
GO TO 200
180 RUN=RUN+1.0
UP=1.0
ITEST=0
IF (RUN=1.0) 40,40,190
190 TREC1=10.*ALOG10(TREC1)
PRINT 220, TREC1,TZ, TLEV,FREQ,T6DP,RTG
RETURN

START BOUNCE FREE RAYS

200 PHI1=PHIG
CZ1.0
DPII=2.5/RTG
IF (DPII.GT.0.05) DPII=0.05
ITEST=0
TINT1=1.0E-35
GO TO 50
210 KP1=KP1-1
YLAST=Y0
GO TO 110

220 FORMAT (/F12.11 DB SIG REC AT,'F7.0,'FT FROM', 'F7.1,'DB TARGET
1 AT', 'F6.4,'KH2','F6.0,'FT DEPTH', 'F8.3,'-KTD', /H1)
230 FORMAT (/30X,'REC ANGLE','5X','TARGET LEVEL'/33X,'DEG','10X','DB/M PA
1'/)
240 FORMAT (28X,'F10.3','5X','F10.2)
END

SUBROUTINE VERTEX (ZLO,ZHI)

THIS SUBROUTINE COMPUTES HIGHEST AND LOWEST DEPTHS REACHED BY RAY

COMMON /COMV/ XZ,ZTG,RMAX,PHID,DELP,HNC,OUTPT,SPD,GR,SNPLT,S
15PLT,ALAT,BERG,HOUR,ACTIV,RAIN,HFLG,ZIG1,ZTGN,ZTINC,RGTRGND,GR
2GINC,TARG,TARG6,TARG7,TARG9,SHIPD,SFLR,SHLS,COMA/AVELP(30)
3,AHB(30),ARESP(30),ASHP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
4,NUMB,NUMS,NUMBW,NUMP,NUMF/COMC/CV,TANPHS
C N=1
10 N=N+2
    ZN=AVELP(N)
    IF (ZN.LT.ZX) GO TO 10
    NST=N-2
C C SEARCH UP
    ZNP1=AVELP(N)
    CNP1=AVELP(N+1)
    N=NST
20 ZN=AVELP(N)
    CN=AVELP(N+1)
    IF (CN.GE.CV) GO TO 30
    CNP1=CN
    ZNP1=ZN
    N=N+2
    IF (N.GT.0) GO TO 20
    ZHI=0.0
    GO TO 50
30 GRAD=(CN-CN1)/(ZN-ZNP1)
    IF (GRAD.EQ.0.0) GO TO 40
    ZHI=ZNP1+(CV-CNP1)/GRAD
    GO TO 50
40 ZHI=ZNP1
C C SEARCH DOWN
50 CONTINUE
    ZN=AVELP(NST)
    CN=AVELP(NST+1)
    N=NST+2
60 ZNP1=AVELP(N)
    CNP1=AVELP(N+1)
    IF (CNP1.GE.CV) GO TO 70
    CN=CNP1
    ZN=ZNP1
    N=N+2
    IF (N.LT.NUMV) GO TO 60
    ZLO=AVELP(N-2)
    RETURN
70 GRAD=(CN1-CN)/(ZNP1-ZN)
    IF (GRAD.EQ.0.0) GO TO 80
    ZLO=ZN+(CV-CN)/GRAD
    RETURN
80 ZLO=ZN
    RETURN
C END