AD-760 692

# RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL

R. A. Wagstaff

Naval Undersea Center

Prepared for:

Naval Ship Systems Command

April 1973

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NUC TP 349

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by R. A. Wagstaff
Undersea Surveillance and Ocean Sciences Department

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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.

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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.

UNCLASSIFIED
Security Classification

**DOCUMENT CONTROL DATA - R & D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY *(Corporate author)*<br>Naval Undersea Center<br>San Diego, Calif. 92132 | 2a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED<br>2b. GROUP |

3. REPORT TITLE

RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Research report, June 1971–October 1972

5. AUTHOR(S) *(First name, middle initial, last name)*

R. A. Wagstaff

| | | |
|---|---|---|
| 6. REPORT DATE<br>April 1973 | 7a. TOTAL NO. OF PAGES<br>82 | 7b. NO. OF REFS<br>13 |
| 8a. CONTRACT OR GRANT NO<br>b. PROJECT NO NAVSHIPS Project No. SF 55 2070<br>c.<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>NUC TP 349<br>9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* | |

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY<br>Naval Ship Systems Command<br>Washington, D.C. 20360 |

13. ABSTRACT

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 propagat on conditions and for different sensor depths. Results agree well with experimental da:a, 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.

DD FORM 1 NOV 65 1473 (PAGE 1)
0102-014-6600

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

| 14 KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Ambient noise | | | | | | |
| Vertical directionality | | | | | | |
| Horizontal directionality | | | | | | |
| Noise calculation | | | | | | |
| Computer model | | | | | | |
| Depth dependence | | | | | | |
| Noise sources | | | | | | |
| Target noise | | | | | | |
| Underwater acoustics | | | | | | |

DD FORM 1 NOV 65 1473 (BACK)
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CONTENTS


INTRODUCTION 1

BACKGROUND 1

AMBIENT NOISE DIRECTIONALITY MODEL 3

Model Description 3
Mathematical Description 4
Computational Procedure 8
Model Calibration Procedure 9
Model Validation 9

DISCUSSION OF RESULTS 10

General Results 10
Model Output–Measured Data Comparison 14

FUTURE IMPROVEMENTS 16

SUMMARY 16

REFERENCES 18

Appendixes:
A. RANDI SUBROUTINE DESCRIPTIONS AND FLOW DIAGRAM 19
B. RANDI INPUT–OUTPUT 22
C. RESEARCH AMBIENT NOISE DIRECTIONALITY (RANDI) MODEL LISTING 40


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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.

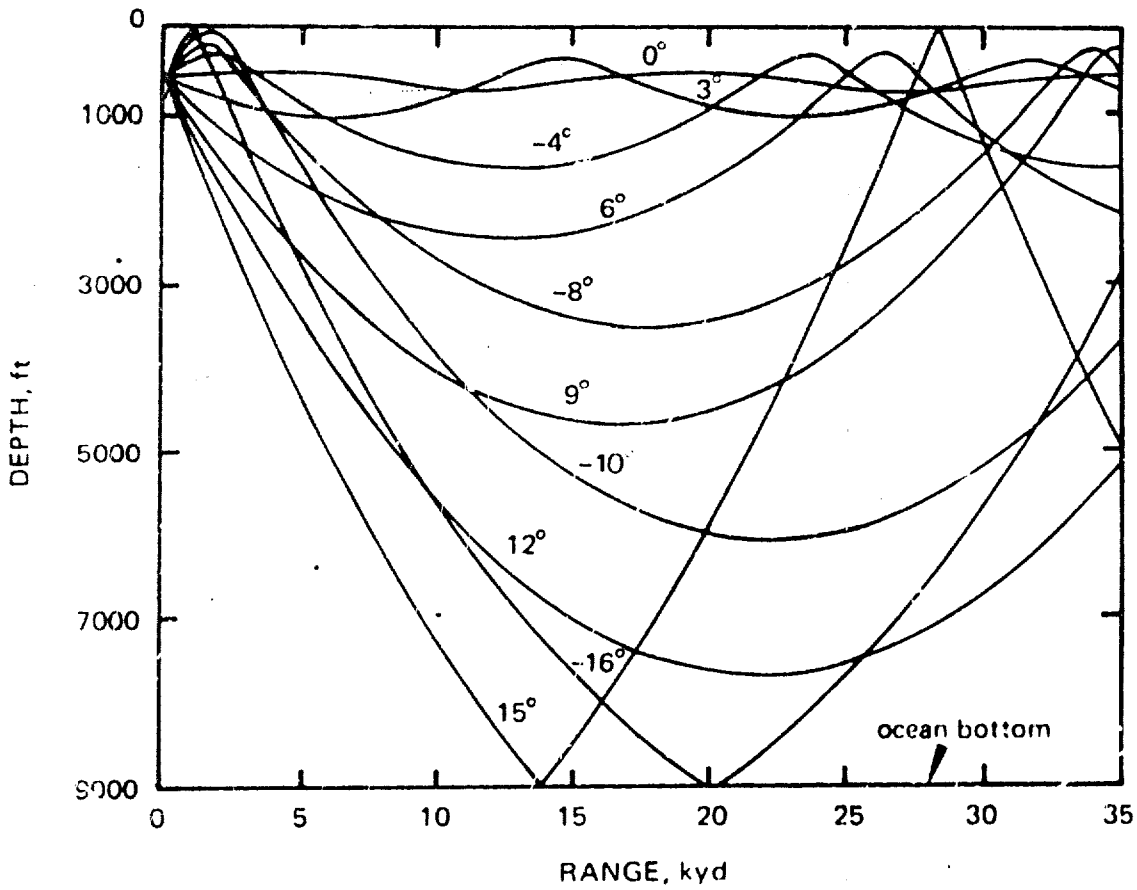


Figure 1. Typical raytrace diagram.

The net effect of propagating—to 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

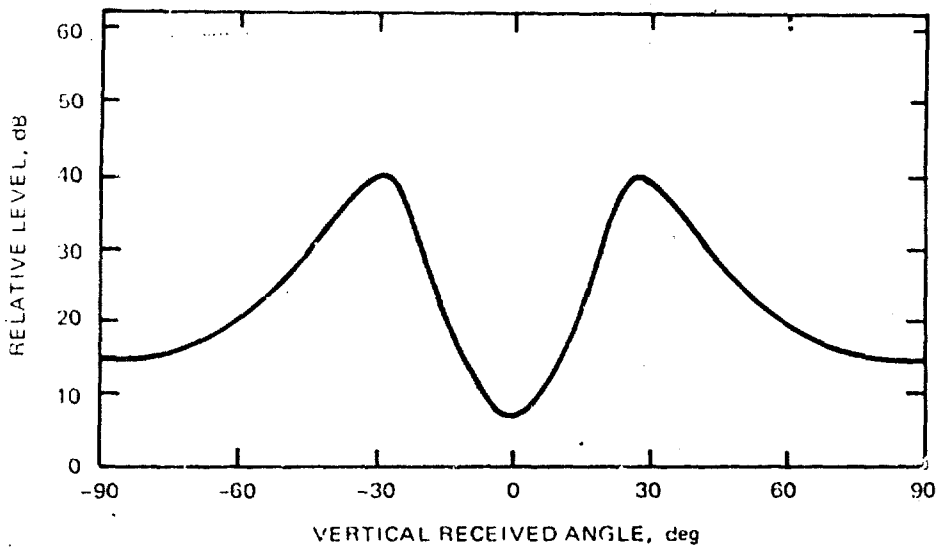


Figure 2. Typical ambient noise vertical directionality plot.

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:

$$\mathrm{SNL}\ (\mathrm{re}\ \mu\mathrm{Pa}) = A_0 - 10 \log \left(10^{-1.0 \log f' + 1.16} + 10^{+3.3 \log f' - 6.27}\right)$$

$$+ 4\ \mathrm{SHIPD} + 50 \log (\mathrm{SPEED}/12) + 20 \log (\mathrm{LENGTH}/300)$$

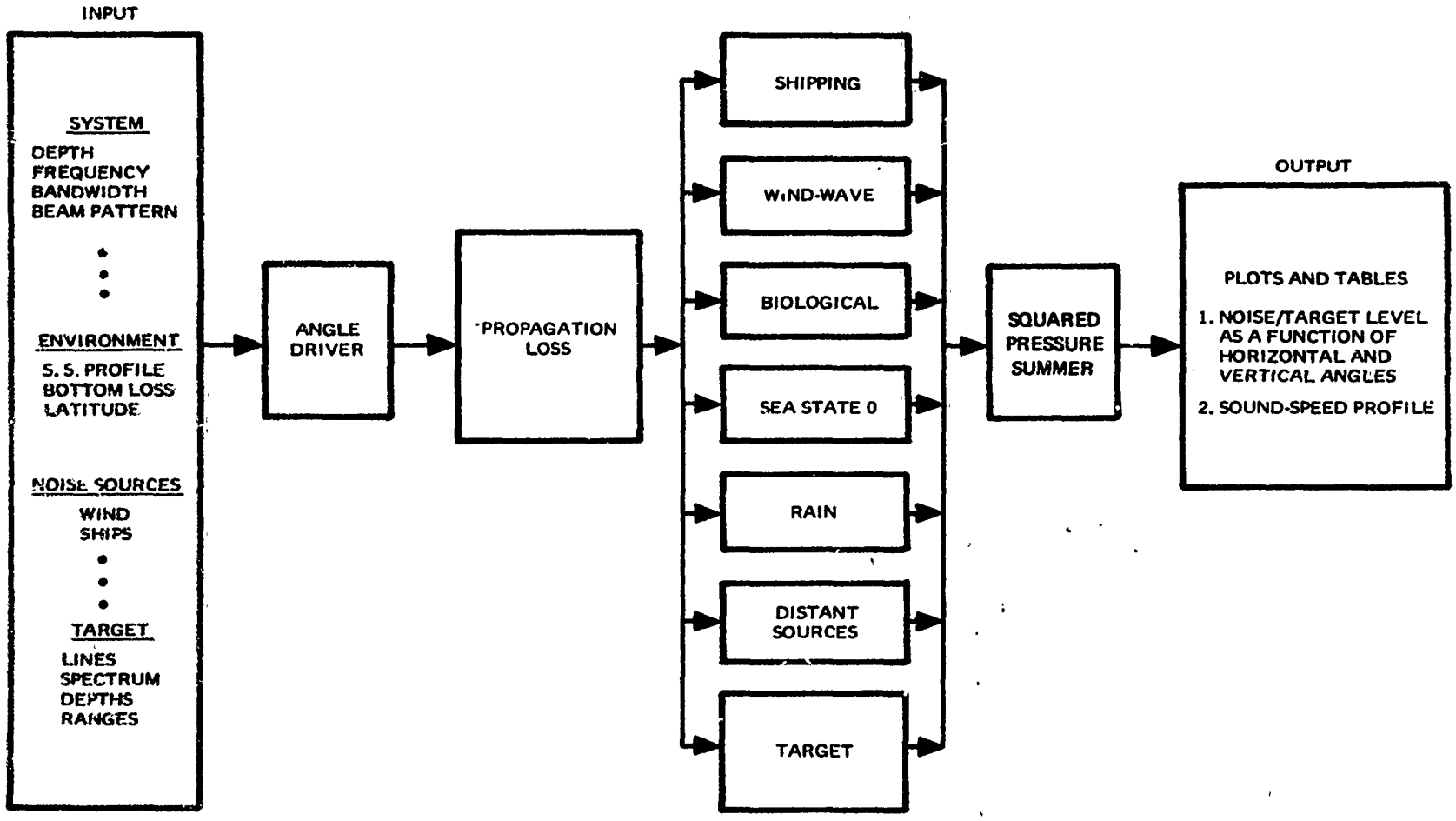


Figure 3. RANDI model block diagram.

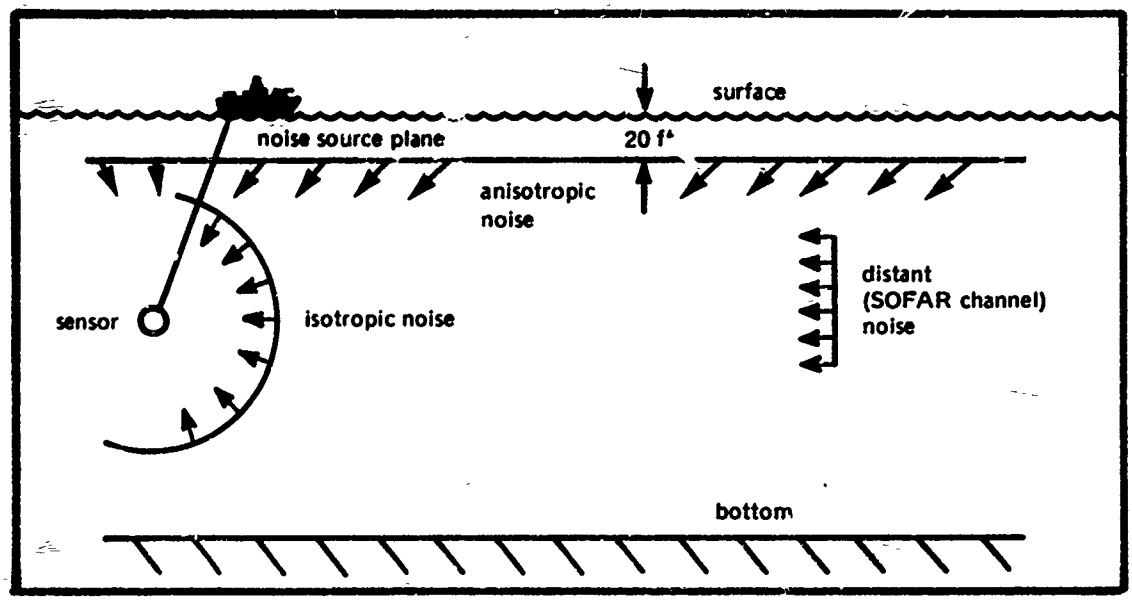


Figure 4. RANDI model noise field.

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 ASHIP (ship density vs range array) or a shipping density indicator 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 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 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:

$$\text{WNL (re } \mu\text{Pa)} = -18 \log f + 96$$

$$+ [9.66 (\log f)^2 - 26 \log f + 27.3](0.065\ \text{WSPD}^{0.7})$$

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:

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

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

$$n = \begin{cases} \dfrac{90 - \phi}{10} & 0 \leqslant \phi \leqslant 70 \\ 2 & 70 \leqslant \phi \leqslant 90 \end{cases}$$

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.

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

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):

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

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:

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

$$- 16.96 (\log f)^2 + 50.1 \log f + 45.1$$

where the $0 \leq$ 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

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

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

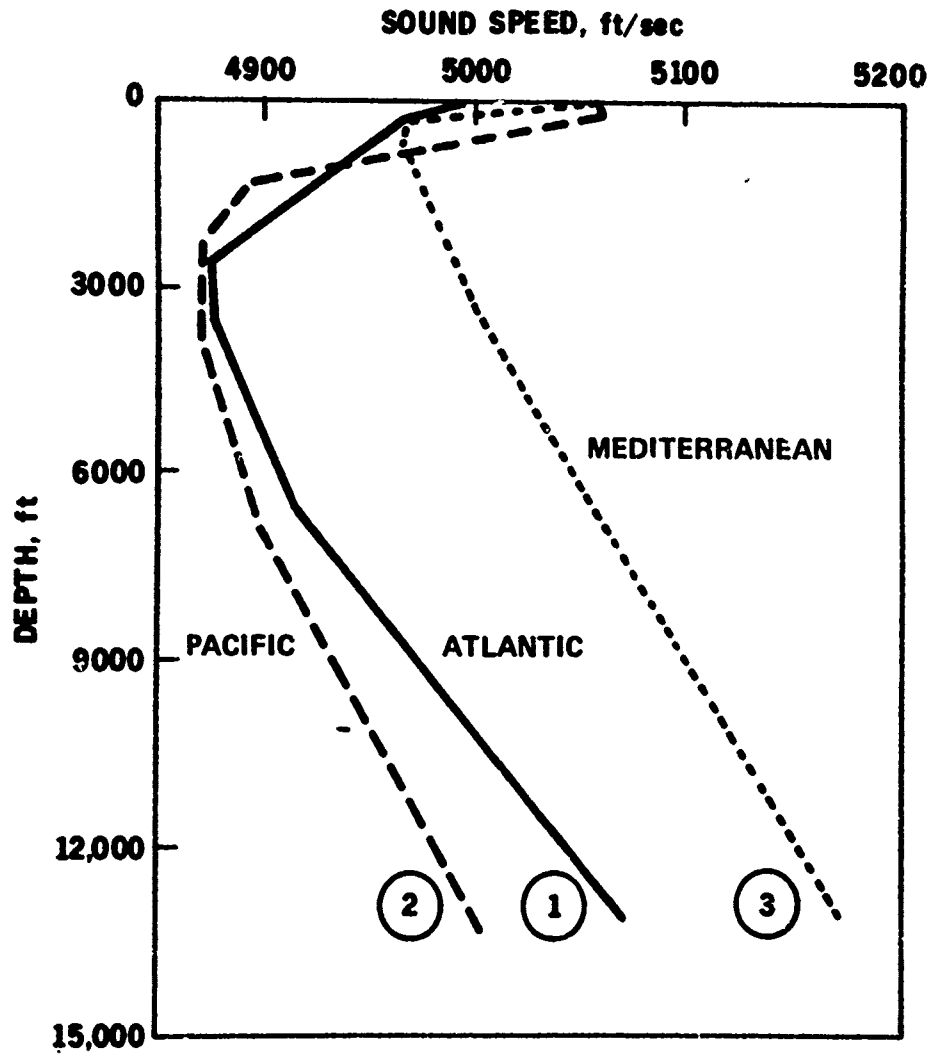


Figure 5. Sound-speed profiles for Areas 1, 2, and 3.

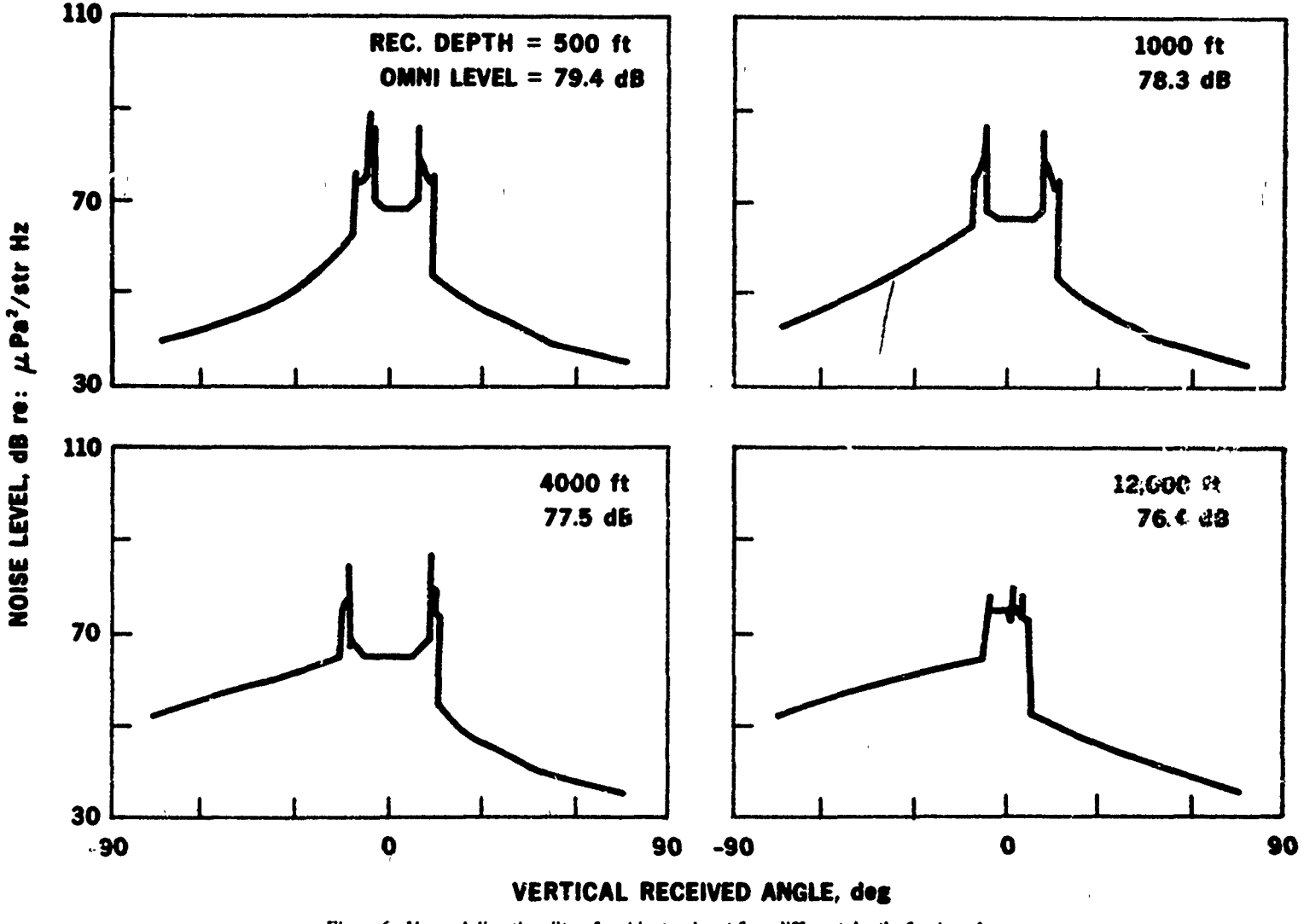


Figure 6. Vertical directionality of ambient noise at four different depths for Area 1.

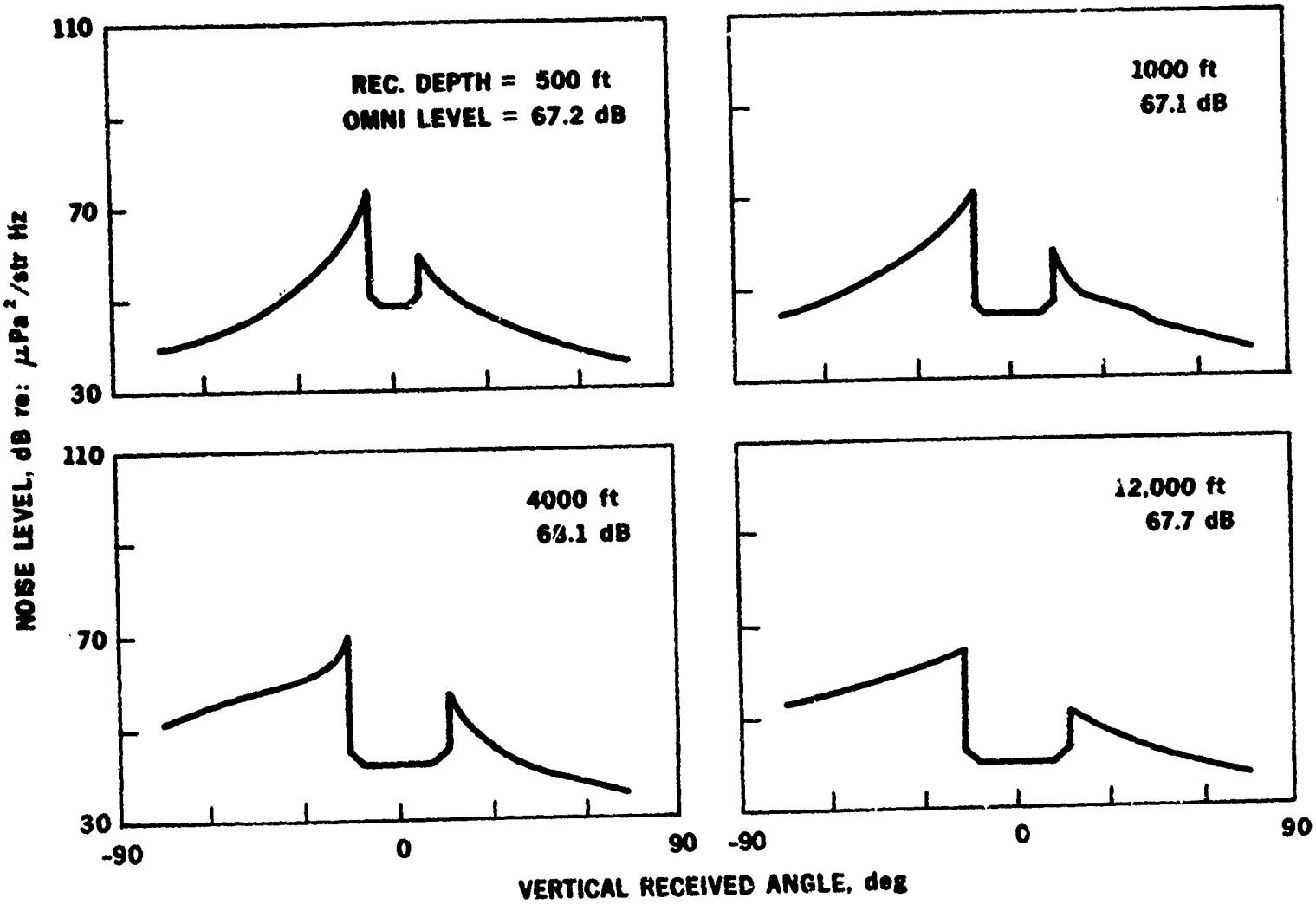


Figure 7. Vertical directionality of ambient noise at four different depths for Area 2.

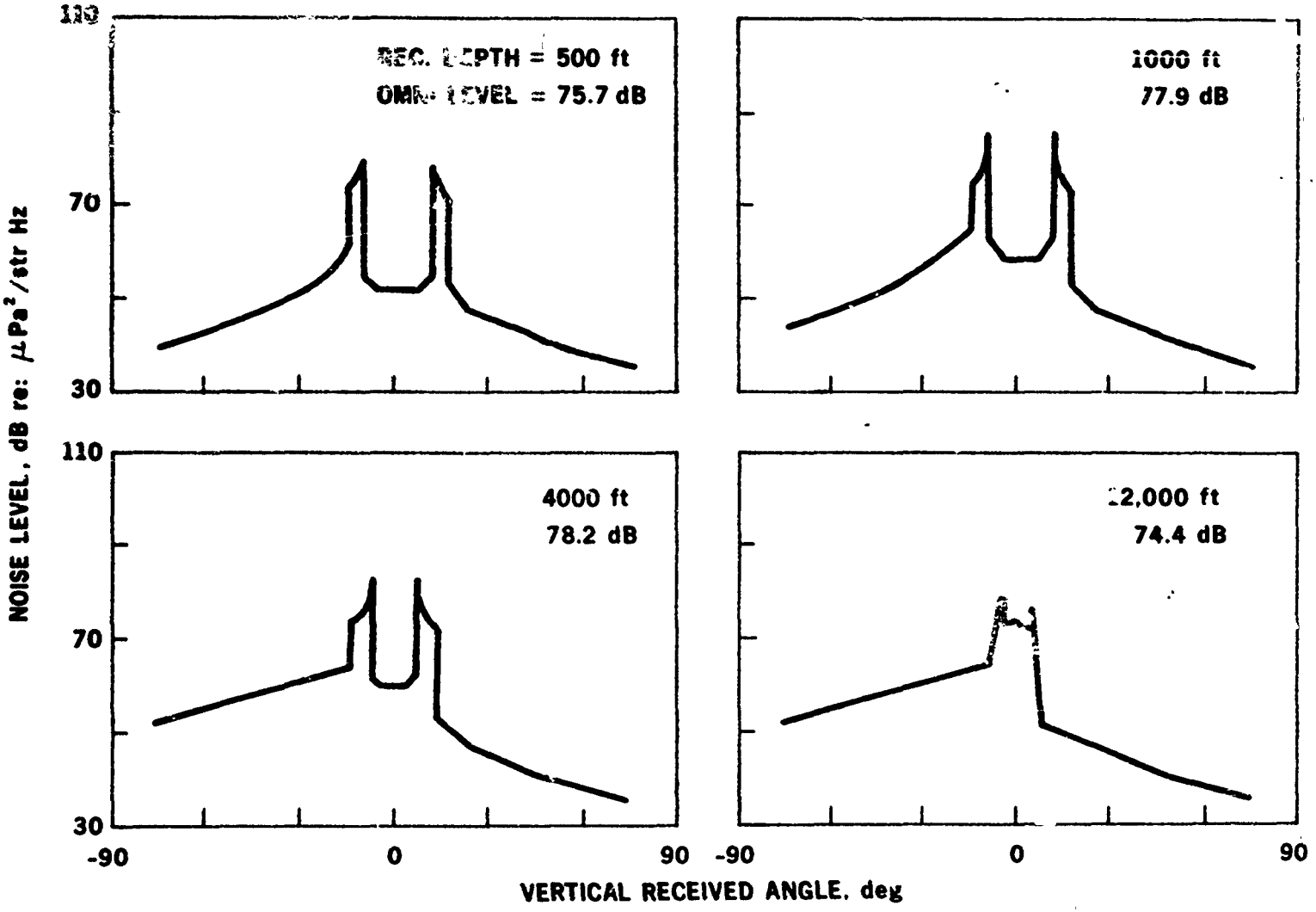


Figure 8. Vertical directionality of ambient noise at four different depths for Area 3.

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

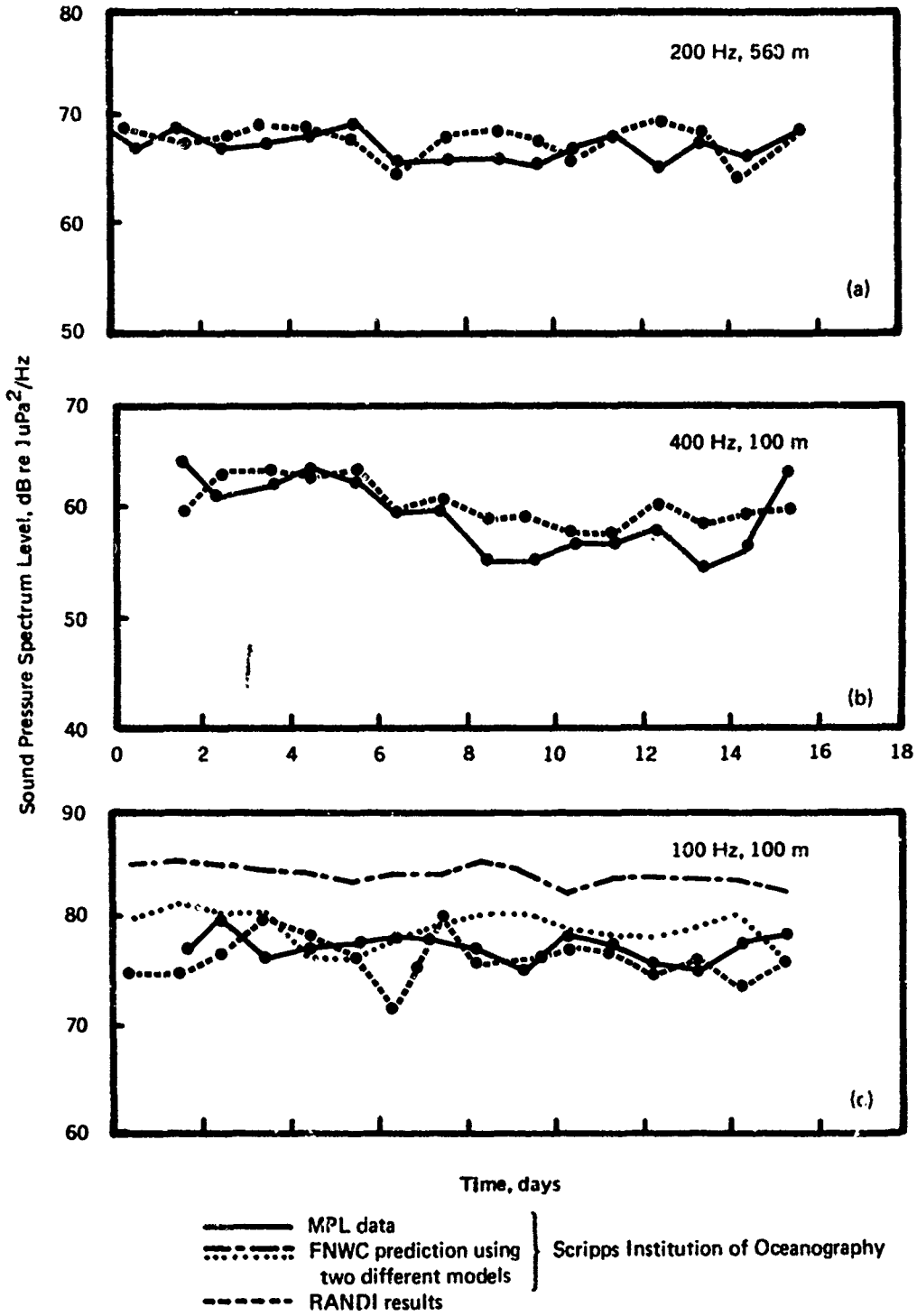


Figure 9. RANDI model–measured data comparison for several frequencies and depths (Ref. 11).

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 Frassetto 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.

Table 1. Comparison of RANDI Output and Measured Noise Pressure Spectrum Level Data From the Mediterranean (Ref. 13).

| Frequency, Hz | Depth, ft | Difference in Level, dB |
|---|---|---|
| 20 | 925 | −1.0 |
| | 1728 | −0.6 |
| | 3785 | ... |
| | 5795 | −1.9 |
| | 6730 | −1.8 |
| 50 | 925 | 1.9 |
| | 1728 | 2.6 |
| | 3785 | 0.4 |
| | 5795 | 2.7 |
| | 6730 | 4.5 |
| 100 | 925 | 0.5 |
| | 1728 | 0.0 |
| | 3785 | 0.3 |
| | 5795 | 1.1 |
| | 6730 | 2.4 |
| 200 | 925 | −1.2 |
| | 1728 | −1.6 |
| | 3785 | −2.8 |
| | 5795 | −0.5 |
| | 6730 | −0.1 |
| 400 | 925 | 0.2 |
| | 1728 | 0.3 |
| | 3785 | −1.6 |
| | 5795 | −1.6 |
| | 6730 | −0.4 |
| 500 | 925 | 0.5 |
| | 1728 | −0.7 |
| | 3785 | −0.5 |
| | 5795 | −1.6 |
| | 6730 | −1.1 |

## REFERENCES


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4. Naval Air Development Center. Technical Memorandum 69-008-1, A Model for Ambient Noise Due to Shipping, by C. L. Bartberg, 31 December 1969

5. Naval Undersea Research and Development Center. Technical Note 649, Active Sonar Performance Prediction Model, by W. H. Watson and R. W. McGirr, November 1971.

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7. Naval Underwater Sound Laboratory. Report 1049, Ambient Noise Spectrum Levels as a Function of Water Depth, by A. J. Perrone, November 1969.

8. Scripps Institution of Oceanography. Ref. 61–4, The Directional Distribution of Ambient Noise in the Ocean, by A. B. Becken, March 1961.

9. David Taylor Model Basin. Report C627, Laboratory Study of the Underwater Sound from the Splashes of a Spray of Water Droplets, by G. J. Franz, July 1955.

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11. Personal communication.

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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. |

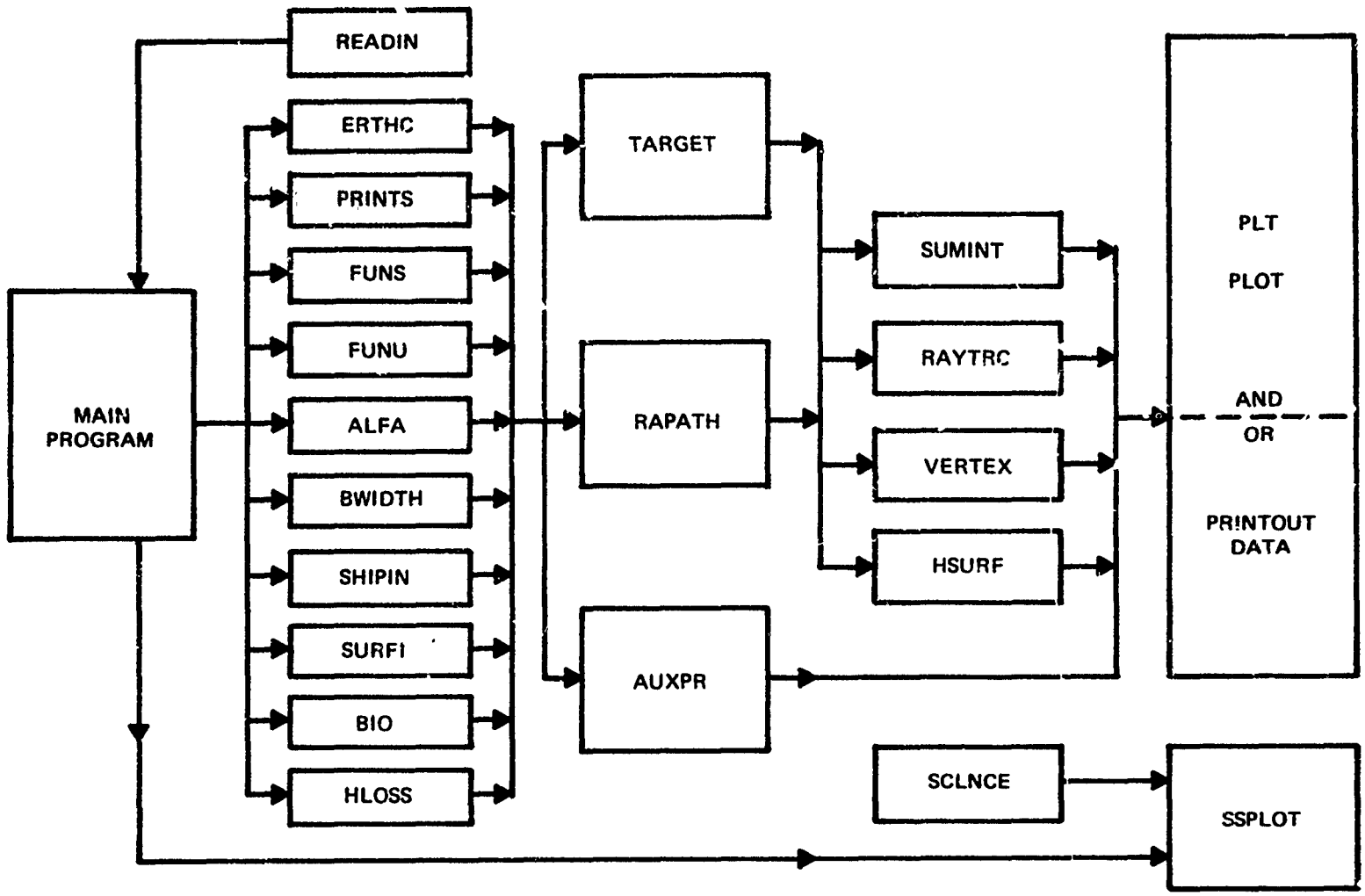


Figure A-1. RANDI subroutine flow diagram.

| | |
|---|---|
| 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

System

| Name | Units | |
|---|---|---|
| ADANF | ARRAY | Frequency (kHz) and depth (ft) array |
| ZTG | FEET | Noise source depth |
| PHID | DEG | Declination–elevation angle |

| Name | Units | |
|---|---|---|
| DELPH | DEG | Vertical half-power beamwidth |
| DGREH | DEG | Width of horizontal sector |
| BERNG | DEG | Bearing of horizontal sector |
| BNCS | | Number of ray bounces |
| ABW | ARRAY | Frequency response (dB down) across bandwidth |
| ARESP | ARRAY | Vertical beam response (dB down) pattern |

## ENVIRONMENTAL

| | | |
|---|---|---|
| ALAT | DEG | Latitude for earth curvature effects |
| AVELP | ARRAY | Sound-speed (ft/sec) vs depth (ft) profile |
| AHB | ARRAY | Bottom reflection loss (dB) vs grazing angle (deg) |
| APROP | ARRAY | Optional prop loss (dB) vs range (kyd) with elevation angle (deg) and ray bundle width (deg) |

## NOISE SOURCES

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

## TARGET

| | | |
|---|---|---|
| ZTG1 | FT | Target depth |
| ZTGNO | | Number of target depths |
| ZTING | FT | Target depth increment |
| RGT | KYD | Range to target |
| RGTNO | | Number of target ranges |
| RGINC | KYD | Target range increment |
| TARG | | If less than 0 TARG0 is a target line component in dB/micropascal, otherwise TARG0 is const in target spectrum level equation |
| TARG0 | | Level of line component in dB or const in spectrum equation |
| TARG1 | | Coefficient of log f |
| TARG2 | | Coefficient of $(\log f)^2$ |
| TARG3 | | Coefficient of $(\log f)^3$ |

## 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

Input

An example of a typical RANDI 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.

```
        END
03 23 72
 06100W  2400N
  EXAMPLE NOISE PLOTS'
   END-DATA
    EXAMPLE PLOTS
    HEADER
     ALAT=24,WSPD=5,SNPLT=1,SSPLT=1,SHLFS=50,OUTPT=1
      ADANF=.05 975
      ASHIP=93 1.9 -12 -300 154 5 -290 215 2.9 -12 277 2.1 -11.5 337
       AHR=0 0 18 0 38 4 55 6 90 6
        * 19685 5111
         AVELP=0 5033 328 5033 656 5000 1640 4987 3280 4902 4920 4898 9514 4957
          $DATA
```

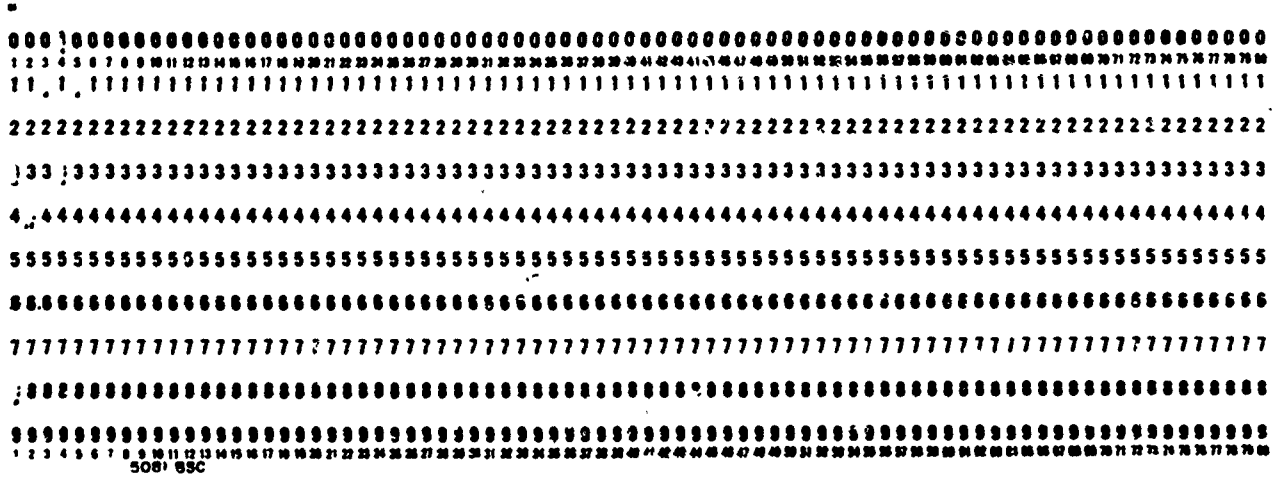


Figure B-1. Example run input data cards.

Reproduced from best available copy.

```
AVFLP=0 5033 328 5033 656 5000 1640 4987 3280 4902 4920 4898 9514 4957
* 19685 5111
AHR=0 0 18 0 38 4 55 6 90 6
ASHIP=93 1.9 -12 -300 154 5 -290 215 2.9 -12 277 2.1 -11.5 337
ADANF=.05 975
ALAT=24,WSPD=5,SNPLT=1,SSPLT=1,SHIFS=50,OUTPT=1
HEADER
EXAMPLE PLOTS
END-DATA
```

** INITIAL PARAMETERS **

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FREQ = | .050 KHZ | ZY = | 975.0 FT | ZTG = | 20.0 FT | PHID = | .0 DEG | DELPH = | 170.0 DEG |
| RNCS = | 10.0 | WSPD = | 5.0 KT | DGREH = | 360.0 DEG | BERNG = | 270.0 DEG | HONR = | 1500.00 |
| ACTIV = | .0 | RAIN = | .0 IN/HR | ALAT = | 24.0 DEG | SNPLT = | 1.0 | SSPLT = | 1.0 |
| HFLAG = | .0 | ZTG1 = | -1.0 FT | ZTGNO = | 1.0 | ZTINC = | .0 FT | RGT = | .0 KYD |
| RGTNO = | 1.0 | RGINC = | .0 KYD | TARG = | .0 | TARG0 = | .0 | TARG1 = | .0 |
| TARG2 = | .0 | TARG3 = | .0 | SHIPD = | 5.2 | SHIFR = | 900.0 NMI | SHIFS = | 50.0 |

| VEL PROFILE | | BOTTOM LOSS | | BEAM RESP | | SHIPPING HISTOGRAM | | | | BANDWIDTH | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FT | FT/SEC | DEG | DB | DEG | DB | NMI | SHIPS | KT | FT | HZ | DB DOWN |
| .0 | 5033.0 | .0 | .0 | -90.0 | .0 | 93.0 | 1.9 | 12.0 | 300. | .0 | .0 |
| 328.0 | 5033.0 | 18.0 | .0 | 90.0 | .0 | 154.0 | 5.0 | | 290. | 1.0 | .0 |
| 656.0 | 5000.0 | 38.0 | 4.0 | | | 215.0 | 2.9 | 12.0 | | | |
| 1640.0 | 4987.0 | 55.0 | 6.0 | | | 277.0 | 2.1 | 11.5 | | | |
| 3280.0 | 4902.0 | 90.0 | 6.0 | | | 337.0 | | | | | |
| 4920.0 | 4898.0 | | | | | | | | | | |
| 9514.0 | 4957.0 | | | | | | | | | | |
| 19685.0 | 5111.0 | | | | | | | | | | |

```
360.0 DEG SECTOR LEVEL =  80.28 DB FOR  50.0 HZ AT  975.0 FT DEPTH

SOFAR CHANNEL PER STR NOISE LEVEL =  77.0 DB FOR 13.9 VERT DEG TOTAL CHANNEL 'LOOK' ANGLE
```

Figure B-2. Typical RANDI initial parameter printout.

| | | | |
|---|---|---|---|
| LOCATION | 06100W 2400N | FREQ (HZ) | 50.0 |
| DATE | 03 23 72 | REC DEPTH (FT) | 975.0 |
| WIND SPEED (KT) | 5.0 | SECTOR LEVEL (DB) | 80.3 |
| BOTTOM DEPTH (FT) | 19685.0 | HOR SEC (DEG) | 360 AT 270 |

| D/E ANGLE (DEG) | NOISE LEVEL (DB) * | D/E ANGLE (DEG) | NOISE LEVEL (DB) * |
|---|---|---|---|
| -76.5 | 46.3 | 76.5 | 40.4 |
| -72.3 | 41.0 | 72.3 | 39.4 |
| -68.0 | 44.0 | 68.0 | 39.0 |
| -65.9 | 44.7 | 65.9 | 38.8 |
| -63.8 | 40.4 | 63.8 | 38.5 |
| -61.6 | 44.1 | 61.6 | 38.5 |
| -59.5 | 43.6 | 59.5 | 38.4 |
| -57.4 | 40.5 | 57.4 | 38.3 |
| -55.3 | 43.5 | 55.3 | 38.4 |
| -53.1 | 43.4 | 53.1 | 38.5 |
| -51.0 | 43.3 | 51.0 | 38.7 |
| -48.9 | 43.3 | 48.9 | 39.0 |
| -46.8 | 43.4 | 46.8 | 39.3 |
| -44.6 | 42.0 | 44.6 | 39.6 |
| -42.5 | 43.8 | 42.5 | 40.1 |
| -40.4 | 45.0 | 40.4 | 40.5 |
| -39.3 | 44.9 | 39.3 | 40.8 |
| -38.3 | 44.9 | 38.3 | 41.2 |
| -37.2 | 45.1 | 37.2 | 41.5 |
| -36.1 | 43.7 | 36.1 | 41.9 |
| -35.1 | 46.6 | 35.1 | 42.5 |
| -34.0 | 44.3 | 34.0 | 42.8 |
| -32.9 | 46.8 | 32.9 | 43.4 |
| -31.9 | 43.7 | 31.9 | 43.7 |
| -30.8 | 48.5 | 30.8 | 44.5 |
| -29.8 | 45.4 | 29.8 | 44.8 |
| -28.7 | 47.8 | 28.7 | 45.6 |
| -27.6 | 48.1 | 27.6 | 46.2 |
| -26.6 | 48.0 | 26.6 | 46.9 |
| -25.5 | 49.0 | 25.5 | 47.6 |
| -24.4 | 49.1 | 24.4 | 48.4 |
| -23.4 | 48.7 | 23.4 | 49.0 |
| -22.3 | 51.1 | 22.3 | 50.1 |
| -21.3 | 51.1 | 21.3 | 50.8 |
| -20.2 | 52.0 | 20.2 | 51.1 |
| -19.1 | 60.3 | 19.1 | 60.6 |
| -18.1 | 60.0 | 18.1 | 60.5 |
| -17.0 | 60.7 | 17.0 | 61.0 |
| -15.9 | 64.0 | 15.9 | 64.4 |
| -14.9 | 64.9 | 14.9 | 65.1 |
| -13.8 | 64.4 | 13.8 | 65.0 |
| -12.8 | 67.6 | 12.8 | 68.1 |
| -11.8 | 69.1 | 11.8 | 69.3 |
| -10.7 | 70.4 | 10.7 | 70.9 |
| -9.6 | 73.6 | 9.6 | 73.4 |
| -8.5 | 72.7 | 8.5 | 74.3 |
| -7.4 | 76.9 | 7.4 | 77.4 |

* DB RE MICROPASCAL**2/STERADIAN HZ

Figure B-3. Typical RANDI noise field vertical directionality printout.

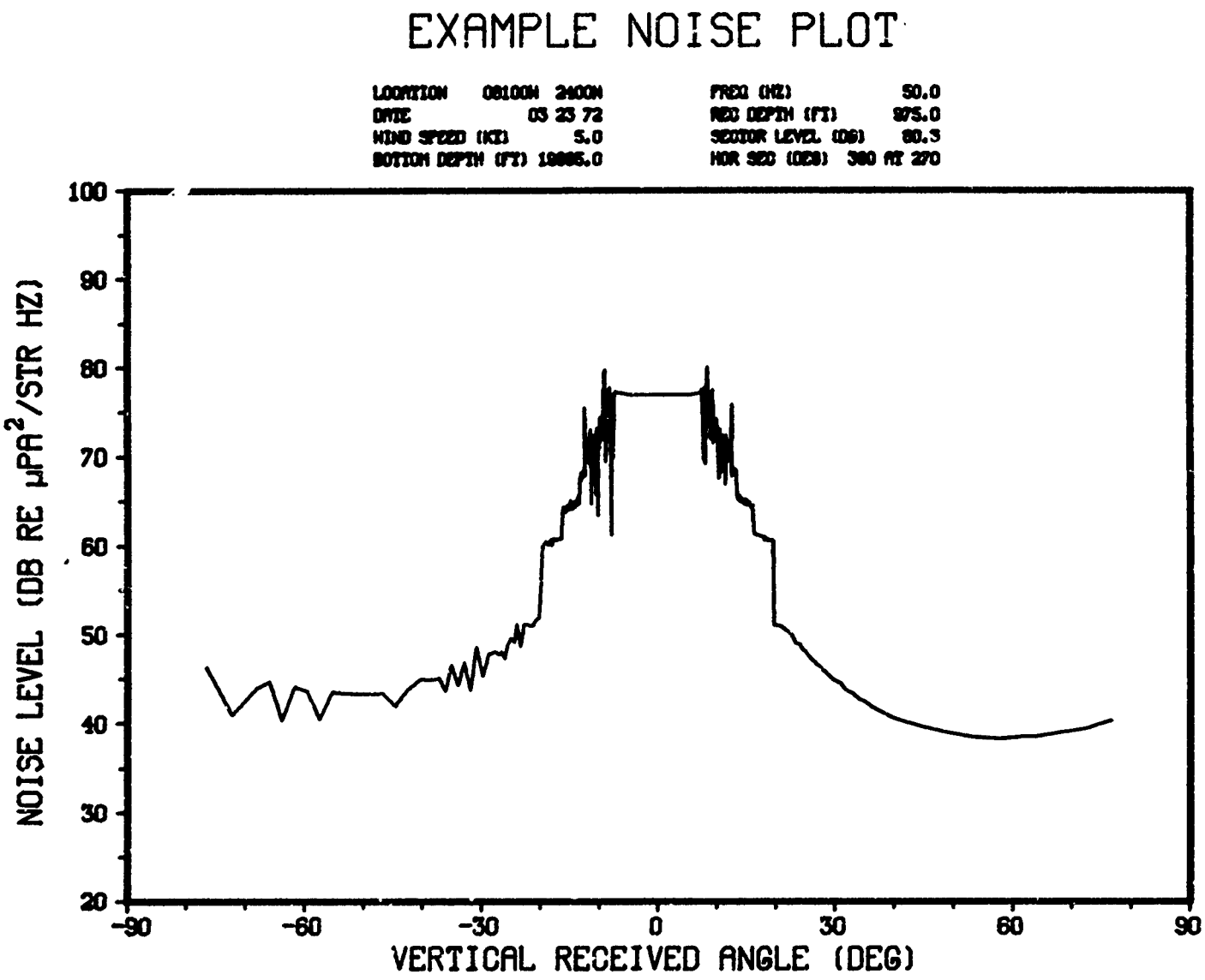


Figure B-4. Typical RANDI vertical directionality plot.

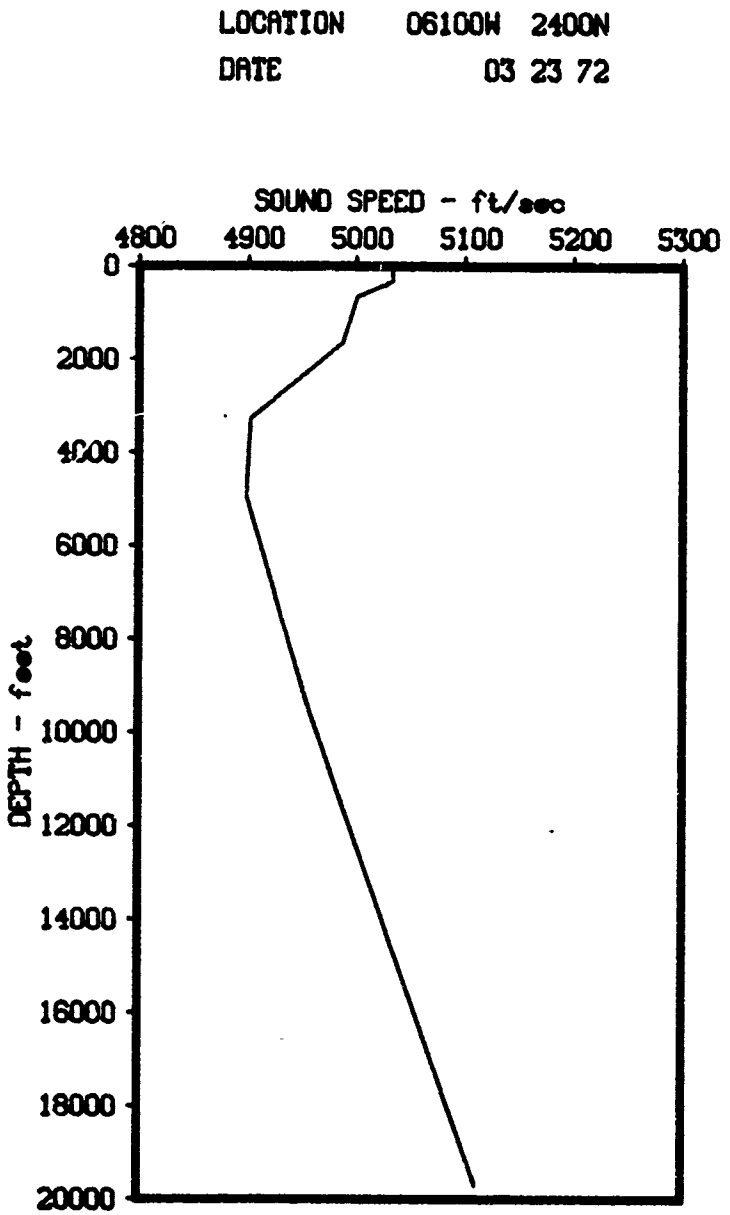


Figure B-5. Typical RANDI sound-speed profile plot.

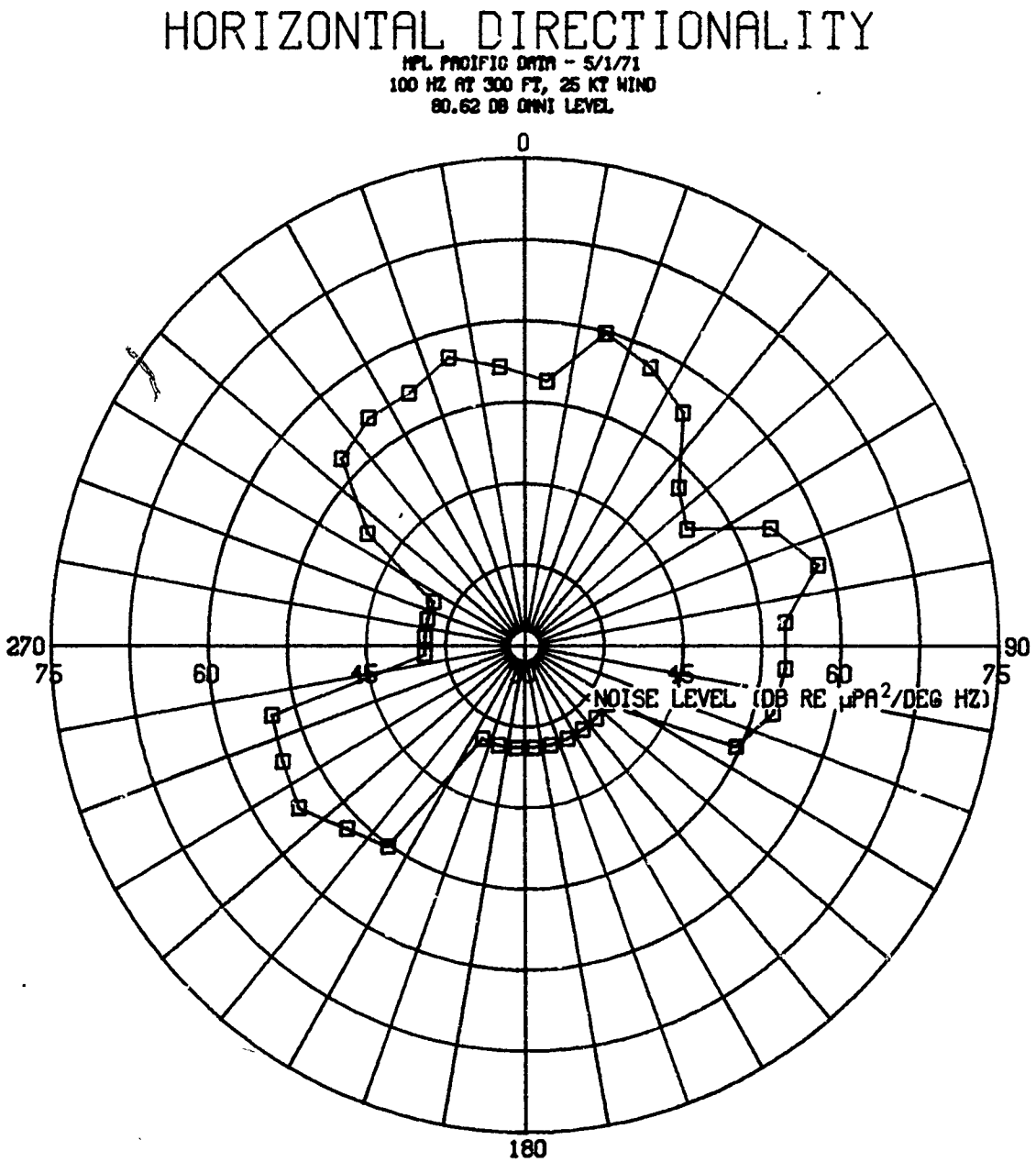


Figure B-6. Per degree horizontal directionality of ambient noise in 10-deg sectors.

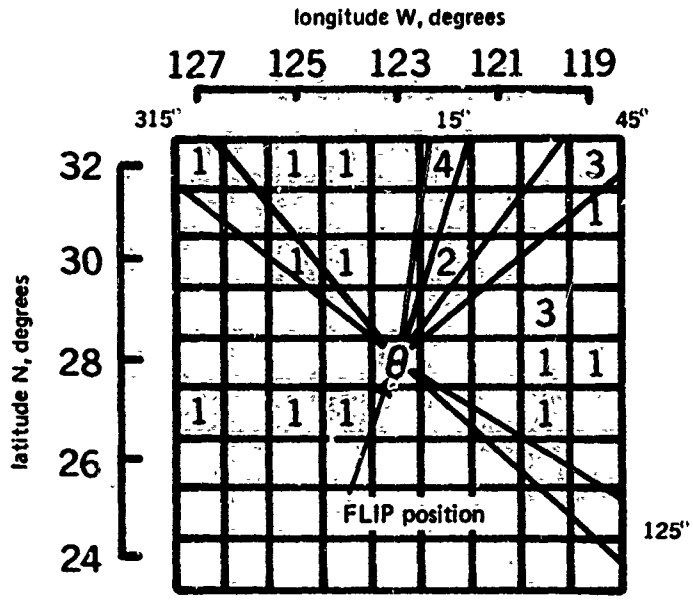


Figure B-7. Pacific shipping data for 1 May 1971. Number of ships over 1000 gross tons per 1-deg square.

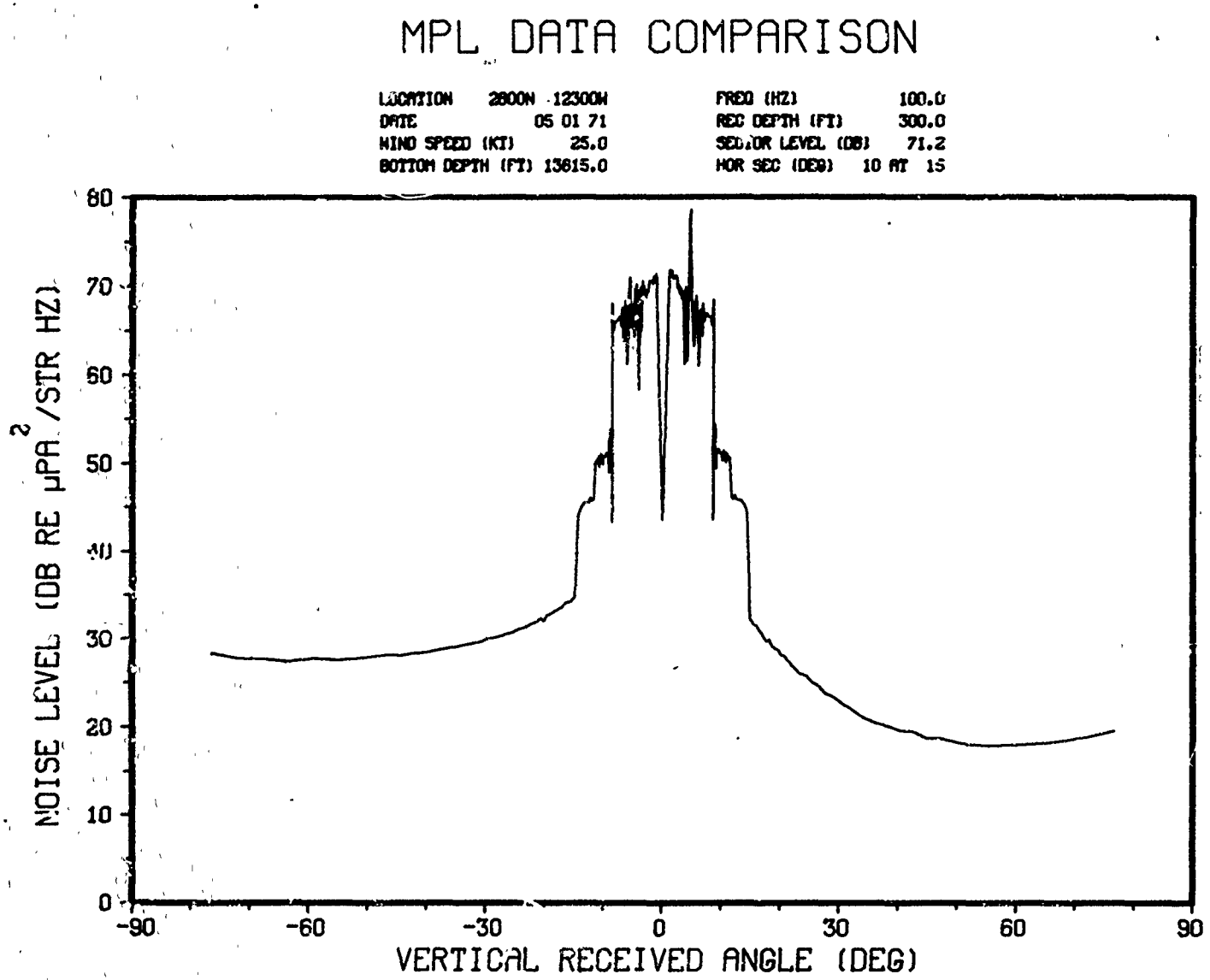


Figure B-8. Ambient noise vertical directionality for the 10-deg horizontal sector at 15 deg.

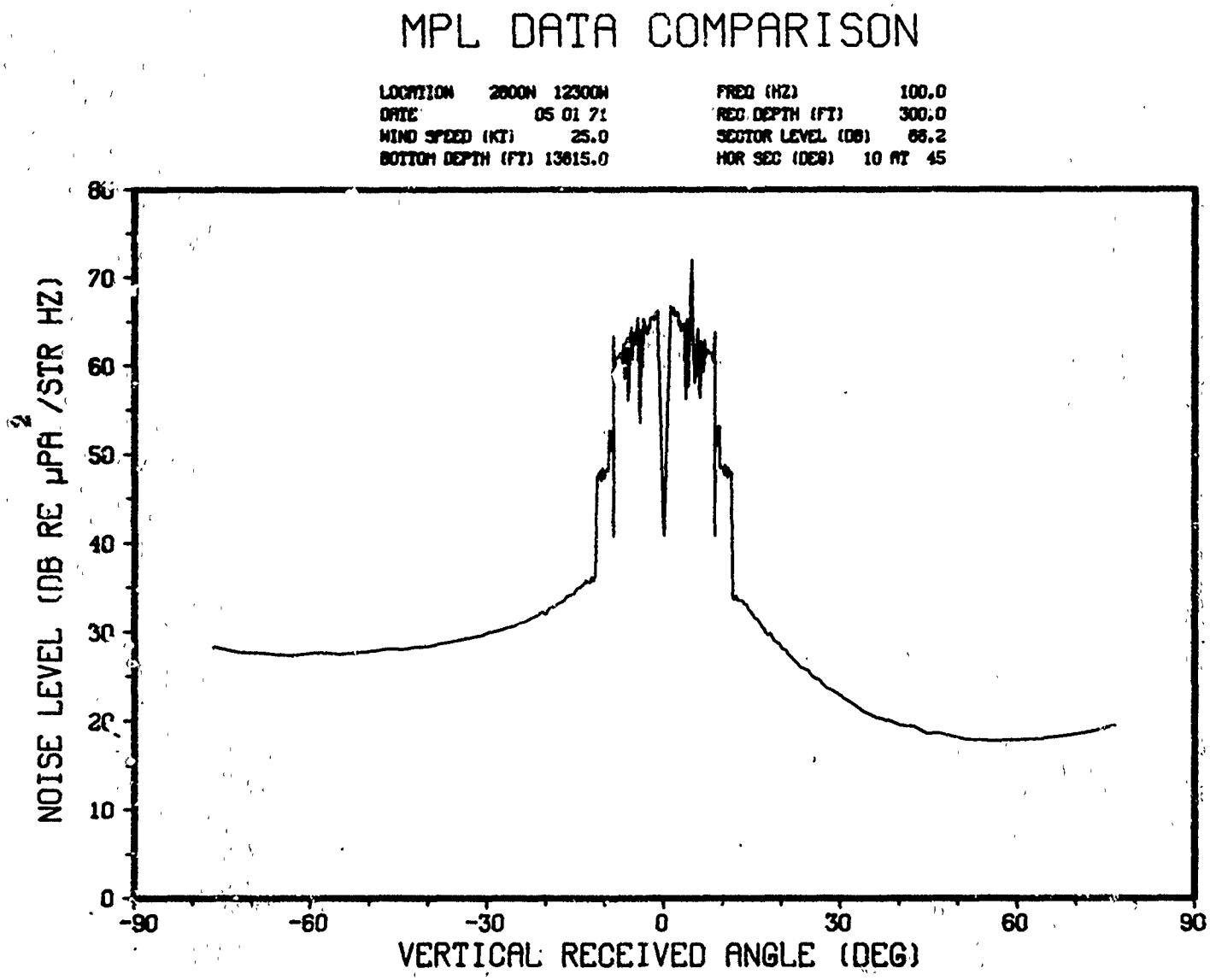


Figure B-9. Ambient noise vertical directionality for the 10-deg horizontal sector at 45 deg.

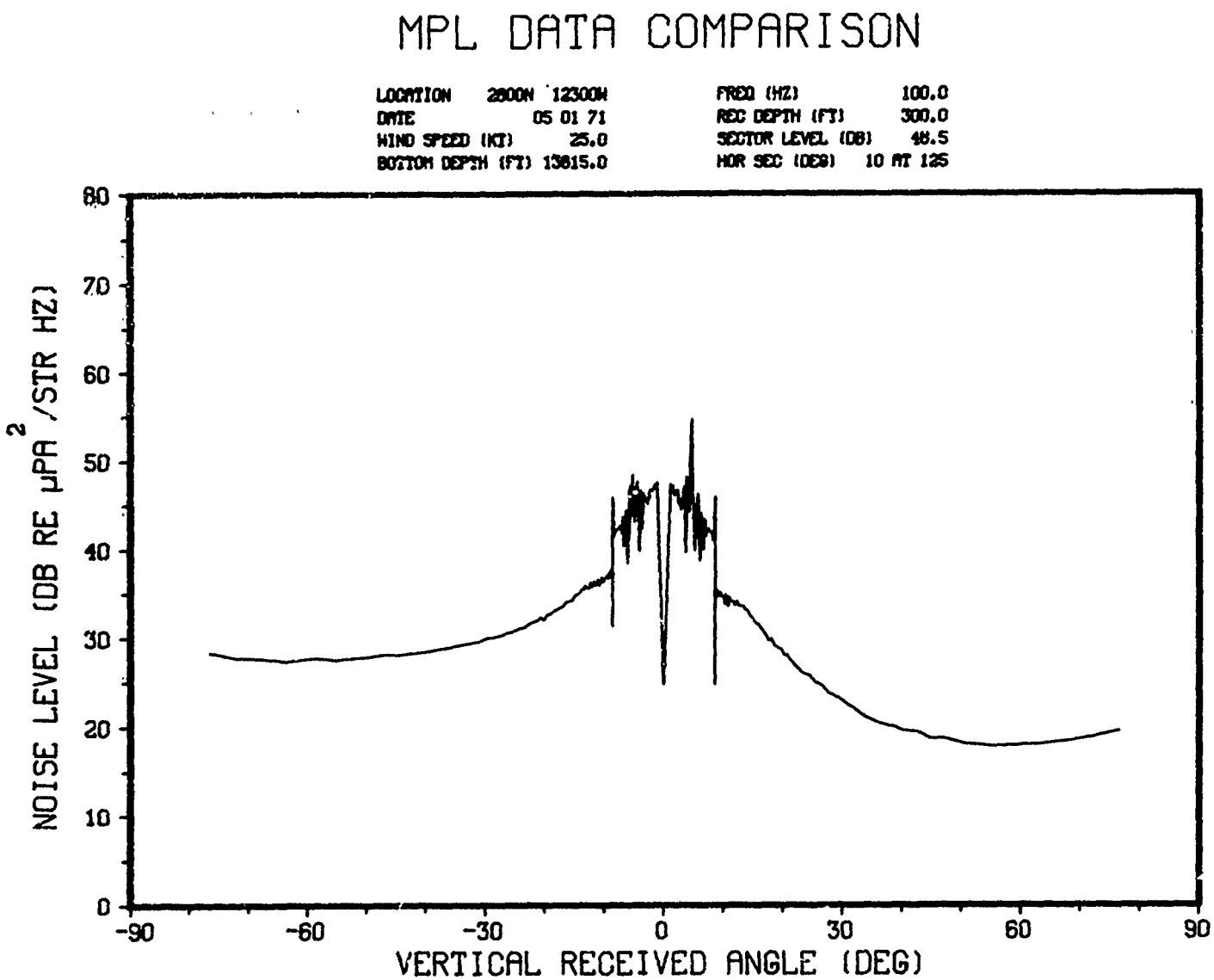


Figure B-10. Ambient noise vertical directionality for the 10-deg horizontal sector at 125 deg.

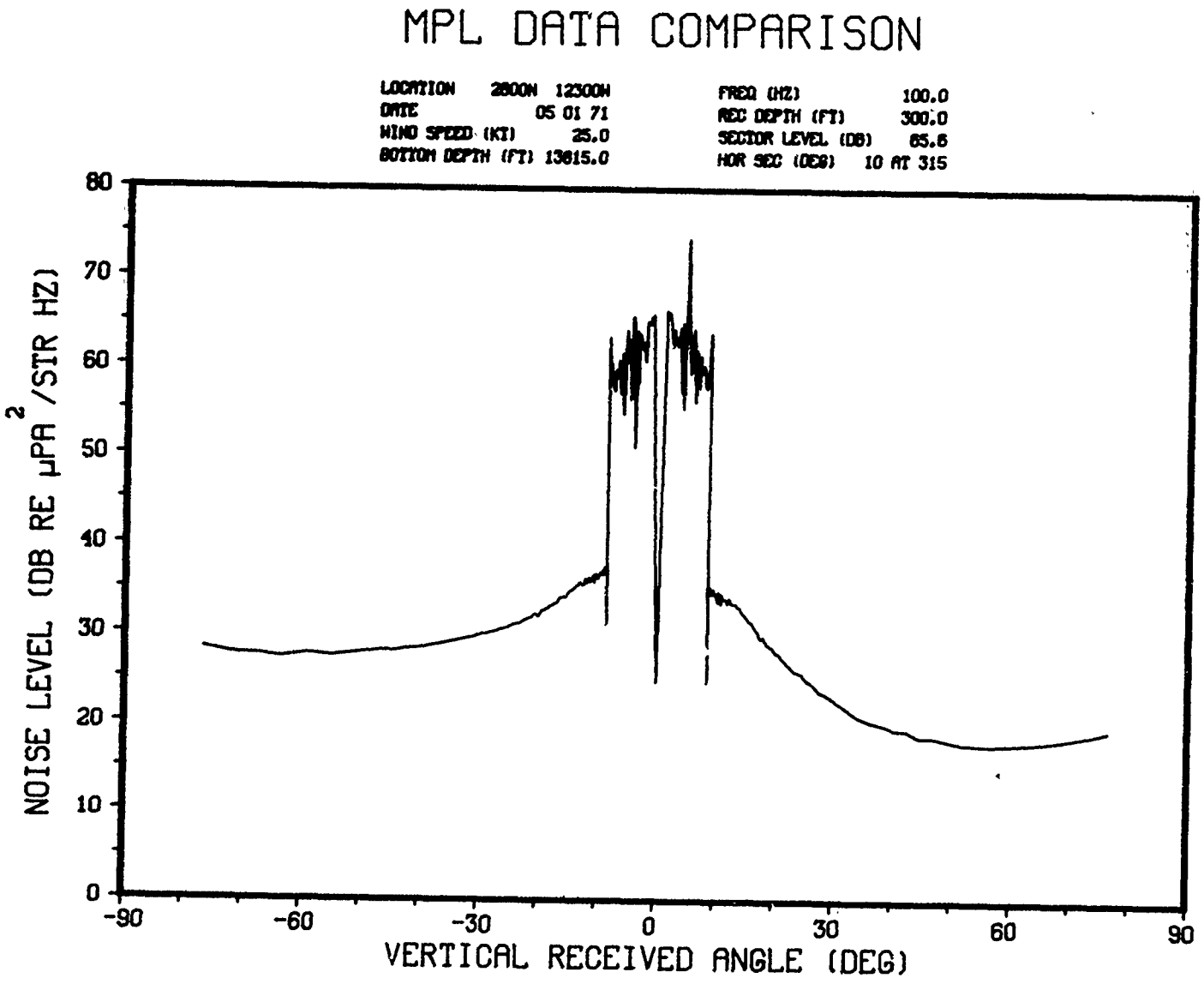


Figure B-11. Ambient noise vertical directionality for the 10-deg horizontal sector at 315 deg.

# TARGET - NOISE PLOT EXAMPLE

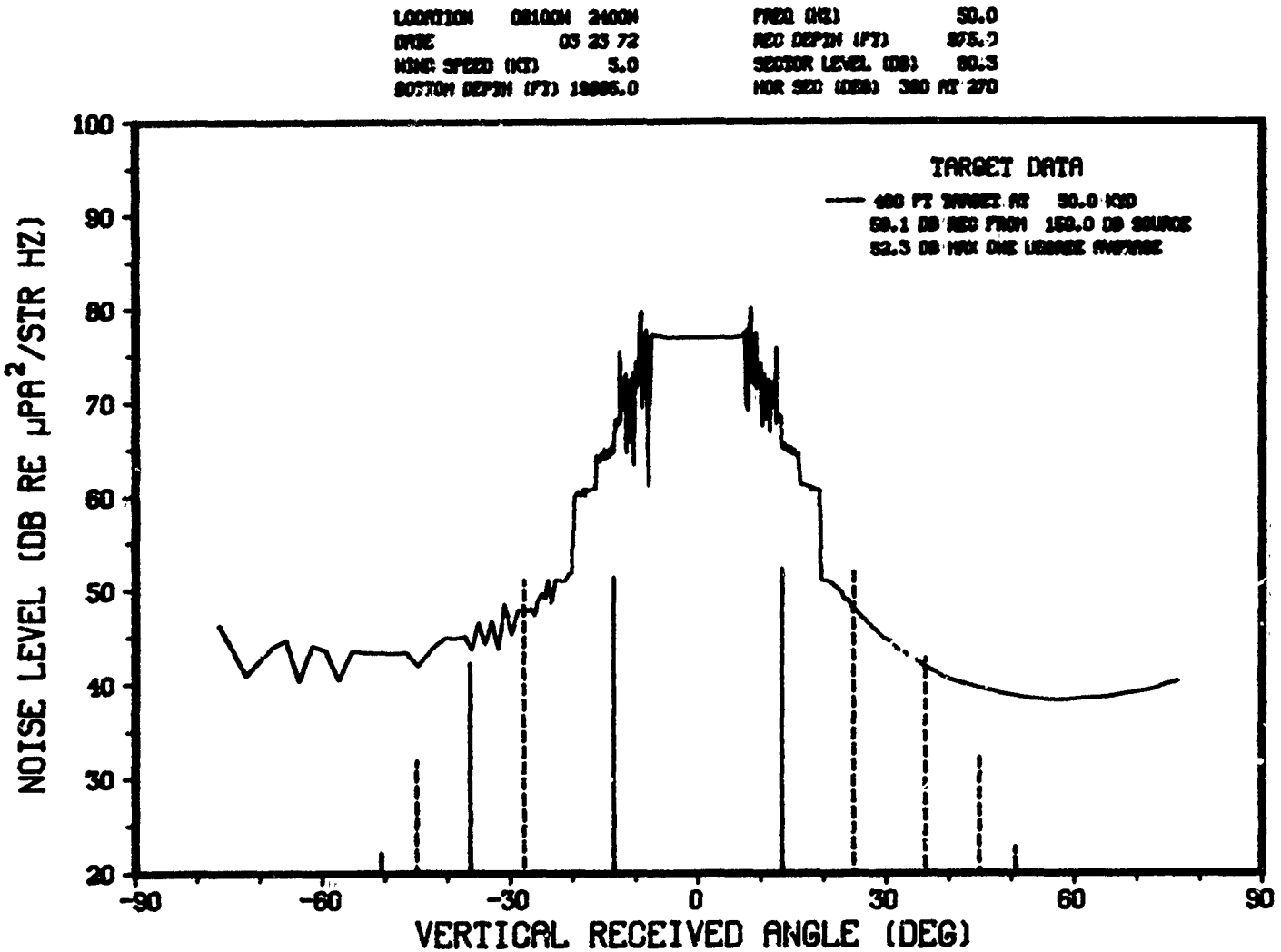


Figure B-12. Example target–ambient noise plot.

| REC ANGLE DEG | TARGET LEVEL DB/M PA |
|---|---|
| -82.135 | -248.50 |
| -79.270 | -140.83 |
| -76.405 | -78.85 |
| -73.540 | -50.95 |
| -70.676 | -29.66 |
| -67.811 | -15.09 |
| -64.946 | -7.88 |
| -62.081 | -.58 |
| -59.216 | 6.88 |
| -56.351 | 14.42 |
| -50.622 | 22.13 |
| -44.892 | 31.94 |
| -36.298 | 42.19 |
| -27.703 | 51.15 |
| -13.380 | 51.42 |
| 82.135 | -247.99 |
| 79.270 | -140.30 |
| 76.405 | -78.33 |
| 73.540 | -50.41 |
| 70.676 | -29.11 |
| 67.811 | -14.55 |
| 64.946 | -7.33 |
| 62.081 | -.02 |
| 59.216 | 7.44 |
| 56.351 | 11.99 |
| 50.622 | 22.72 |
| 44.892 | 32.55 |
| 36.298 | 42.84 |
| 24.839 | 52.29 |
| 13.380 | 52.29 |

58.1 DB SIG REC AT 975. FT FROM 150.0 DB TARGET AT
.0500 KHZ, 400. FT DEPTH, 50.000 KYD

Figure B-13. Example target data output.

Appendix C

# RESEARCH AMBIENT NOISE DIRECTIONALITY (RANDI) MODEL LISTING

```
C          ***********************************************************
C          *                                                         *
C          *   RESEARCH AMBIENT NOISE DIRECTIONALITY (RANDI) MODEL   *
C          *                                                         *
C          ***********************************************************
C
C
C
C                                  ***** MODEL INPUTS *****
C
C        NAME      UNITS                                          INITIAL
C
C** SYSTEM INPUTS **
C
C
C        ADANF     ARRAY     N FREQUENCIES (KHZ) AND K DEPTHS (FT)
C                                N+K .LE. 30
C        ZTG       FEET      NOISE SOURCE DEPTH -                     20
C        PHID      DEG       D/E ANGLE                                 0
C        DELPH     DEG       VERTICAL HALF-POWER BEAMWIDTH           170
C        DGREH     DEG       WIDTH OF HORIZONTAL SECTOR              360
C        BERNG     DEG       BEARING OF HORIZONTAL SECTOR            270
C        BNCS                BOUNCES  .LE. 60                         10
C        ABW       ARRAY     FREQUENCY RESPONSE(DB DOWN) ACROSS
C                                FREQ IN BAND)  1 HZ BW INITIAL
C        ARESP     ARRAY     VERTICAL BEAM RESPONSE PATTERN
C                                OMNI ASSUMED IF NOT INPUT
C
C
C
C** ENVIRONMENTAL INPUTS **
C
C
C        ALAT      DEG       LATITUDE FOR EARTH CURVATURE EFFECTS     40
C        AVELP     ARRAY     VELOCITY(FT/SEC) VS DEPTH(FEET) PROFILE
C        AHB       ARRAY     BOT-REFL LOSS(DB) VS GRAZING ANGLE(DEG)
C                                PROV 5 ASSUMED IF NOT INPUTTED
C        APROP     ARRAY     OPTIONAL PROP LOSS (DB) VS RANGE
C                                (KYD)  ARRAY WITH ELEVATION ANGLE
C                                (DEG) AND RAY BUNDLE WIDTH (DEG)
C                                APROP(1) = DEPRESSION ANGLE (DEG)
C                                APROP(2) = RAY BNDL WDT (DEG)
C                                APROP(2N+1) = RANGE (KYDS)
C                                APROP(2N+2) = PROP LOSS (DB)
C
C** NOISE SOURCE INPUTS **
C
C
C        WSPD      KT        WIND SPEED IN KNOTS                       5
C        ACTIV               BIOLOGICAL ACTIVITY SCALE  0 TO 10        0
C        HOUR      HR        TIME OF DAY IN HOURS (MILITARY)        1500
C        RAIN      IN/HR     RAIN FALL                                 0
C        SHIPD               SHIP DENSITY SCALE  0 TO 7              5.2
C                            .EQ. 0 - NO SHIPS, = 7 - DENSE
C                                SHIPPING CALIB - NPL DATA  4/24/71
```

```
C          ASHIP      ARRAY      SHIPPING HISTOGRAM ARRAY - EACH BAR IS
C                                     DEFINED BY 2 TO 4 NUMBERS IN THE
C                                     FOLLOWING ORDER - RANGE IN NM,
C                                     NO. SHIPS PAST THAT RANGE AND
C                                     BEFORE NEXT RANGE
C                                     NEG AV SHIPS SPEED (KT) (OPTIONAL)  -12
C                                     NEG AV SHIPS LENGTH (FT) (OPT)     -300
C                                     LAST DATA POINT IS LAST RANGE
C          SHLFR      NM         AVERAGE DISTANCE IN NAUTICAL MILES      900
C                                     TO THE CONTINENTAL SHELF AND
C                                     SURFACED SOUND CHANNEL WITHIN THE
C                                     SECTOR OF HORIZ ANGLE (DGREH)
C          SHLFS                 NO. SHIPS WITHIN HORIZ SECTOR OVER        0
C                                     CONT SHELF AND IN SURFACED SOUND
C                                     CHANNEL  (ATLANTIC VLAM DATA CAL)
C

C** TARGET/THREAT INPUTS **       (WHEN PROP LOSS NOT READ IN)
C
C          ZTG1       FT         TARGET DEPTH  .LT. 0 NO TARGET            -1
C          ZTGNO                 NUMBER OF TARGET DEPTHS                    1
C          ZTINC       T         TARGET DEPTH INCREMENT
C          RGT        KYD        RANGE TO TARGET
C          RGTNO                 NUMBER OF TARGET RANGES                    1
C          RGINC      KYD        TARGET RANGE INCREMENT
C          TARG                  .LT. 0.0 TARGO IS A TARGET LINE
C                                     COMPONENT IN DB/MICROPASCAL
C                                .GE. 0.0 TARGO IS CONST IN TARGET
C                                     SPECTRUM LEVEL EQU
C          TARGO                 LEVEL OF LINE COMPONENT IN DB OR
C                                     CONST IN SPECTRUM EQU
C          TARG1                 COEFF OF ALOG10(HZ)
C          TARG2                 COEFF OF ALOG10(HZ)**2
C          TARG3                 COEFF OF ALOG10(HZ)**3
C
C** OUTPUT AND PLOT CONTROL CARDS **
C
C          OUTPT                 OUTPUT DATA CONTROL PARAMETER             -1
C                                     .LE. 0 NO VIRT DIR PRINT OUT - ONLY
C                                     TOTAL SECTOR LEVEL
C          SNPLT                 .LE. 0 NO NOISE PLOT                       0
C          HFLAG                 .GE. 0.0 REQ PLOT DATA CARDS               0
C                                     ELIM PLOT DATA THAT DO NOT CHANGE
C          SSPLT                 .LE. 0 NO VELOCITY PROFILE PLOT            0
C
C
C          THREE ADDITIONAL CARDS REQUIRED AFTER PAUSE FOR NOISE PLOT
C                    (ONLY ONE SET FOR EACH FREQ AND DEPTH LOOP)
C
C          TYPE       FORMAT     EXAMPLE DATA CARD  (IN ORDER)
C
C          TITLE      40A1       AMBIENT NOISE DIRECTIONALITY$'  NOTE  ($')
C          LOCATION   13A1       4020N  01715E
C          DATE       10A1       07 22 71

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

```
C** DATA CONTROL CARDS **
C
C
C          HEADER                 USED BEFORE A MESSAGE STATEMENT
C          PAUSE                  USED BEFORE EACH CONSECUTIVE RUN
C                                     EXCEPT FIRST
C          PRLOSS                 USED BEFORE EACH PROP LOSS ARRAY
C          END-DATA               USED AT END OF DATA OR BEFORE PLOT
C                                     CARDS THAT ARE AT END OF DATA
C
C     ****************************  BEGIN PROGRAM  ***********************
C
C
      DIMENSION FRE4(11),DPTH5(29),FREQ9(29)
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      DATA IPOZ/5HPAUSE/,IPOP/5HPRLOS/
      DATA ZTG/20./,SHLFR/900./,SHLFS/0./,RMAX/500./,OUTPT/-1./
      DATA RADCON/57.2957795/,SHIPD/5.2/,NUMS/9/
      DATA SNPLT,SSPLT,PHID,DELPH,BNCS,WSPD/.0,.0,.0,170.,10.,5.0/
      DATA (AHB(I),I=1,10)/0.,10.,20.,13.6,40.,14.5,50.,16.5,90.,17./
      DATA DGREH/360./,ALAT/40./,NUMH/10/,HOUR/1500./
      DATA ACTIV/.0/,BION/0.0/,RAIN/0.0/
      DATA (ABW(I),I=1,4)/0.0,0.0,1.0,0.0/
      DATA NUMBW/4/,ZTG1/-1.0/,HFLAG/0.0/,ZTGNO/1.0/,RGTNO/1.0/
      DATA (ARESP(I),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/
C
C
   10 CALL READIN (IPOS)
      HFLG1=HFLAG
      JDPTH=0
      JFREQ=0
C
C     SORT FREQ AND DEPTH ARRAY INTO TWO SEPARATE ARRAYS
C
      DO 15 KDF=1,NUMF
      IF (ADANF(KDF) .LE. 2.) GO TO 11
      JDPTH=JDPTH+1
      DPTH5(JDPTH)=ADANF(KDF)
      GO TO 15
   11 JFREQ=JFREQ+1
      FREQ9(JFREQ)=ADANF(KDF)
   15 CONTINUE
      DO 160 L3=1,JDPTH
      ZX=DPTH5(L3)
      DO 160 L4=1,JFREQ
      FREQ=FREQ9(L4)
      IF (L3+L4 .GT. 2) HFLAG=-1.
      PTEST=0.0
```

```
C
C     STORE FOR PRINT OUT ARRAYS THAT CHANGE
C
      IF (VFLAG.GT.0.0) GO TO 20
      DO 20 I=1,NUMV
      AVEL1(I)=AVELP(I)
   20 CONTINUE
      IF (L3+L4 .EQ. 2) CALL PRINTS
      JCNT=0
      TOTLI=0.0
      I51=0
      HORZI=1.0E-18
      IF (FREQ.LT..01.OR.FREQ.GT..5) GO TO 170
C
C     MULTIPLE RUN CHECK
      IF (VFLAG.EQ.0.0) CALL ERTHC
C
C     CALCULATE 11 BANDWIDTH FREQUENCIES
      BANDW=ABW(NUMBW-1)
      FSTRT=.5*(-BANDW+SQRT(BANDW*BANDW+4.0E+6*FREQ*FREQ))
      DO 30 I=1,11
      BB5=I-1
      FRE4(I)=BB5*BANDW*.1
      FRE3(I)=FSTRT+FRE4(I)
      BANDL(I)=FUNU(ABW,FRE4(I),NUMBW)
   30 CONTINUE
C
C     DETERMINE BIOLOGICAL SOURCE
      IF (ACTIV.GT.0.0) CALL BIO
C
C     CALCULATE SURFACE NOISE SOURCE INTENSITIES
      CALL SURF
C
      ALPHAC=ALFA(40.0,FREQ)
      HORZI=1.0E-18
      IF(SHLFS .EQ. 0.0) GOTO 32
C
C     CALCULATE INTENSITY/STERADIAN FOR HOR NOISE DUE TO DISY SOURCES
C     CALIBRATE HOR NOISE WITH VLAM DATA (ASSUME 10 SHIPS OVER SHELF
C     AT 600 NM)
C
      RDIST=SHLFR*2000.
      SHLFD=10.*ALOG10(1.+SHLFS)
      RLOS=-86.+15.*ALOG10(RDIST)+ALPHAC*(RDIST*.001)
      DO 31 J=1,11
      BB1=ALOG10(FRE3(J)+6.)-.25
      SL1=-1.*BB1+1.16
      SL2=3.3*BB1-6.274
      CORL=-38.
   31 DB(J)=-10.-10.*ALOG10(10.**SL1+10.**SL2)-RLOS+SHLFD+CORL
      CALL BWIDTH(HORZI)
C
C     CONVERT TO INTENSITY/HORIZ DEG
C
      HORZI=HORZI*DGREH*.0027777
   32 CONTINUE



      HORDB=10.*ALOG10(HORZI/.109662)+84.8856
C
C     PHICH IS THE HALF ANGLE WIDTH OF SOUND CHANNEL SEEN BY RECEIVER
C     SORSV IS SOUND SPEED AT NOISE GENERATOR DEPTH
C
```

```
      CX=FUNU(AVELP,ZX,NUMV)
      PHICH=0.0
      SORSV=AMIN1(AVELP(2),AVELP(NUMV))
      IF(SORSV .GE. CX) PHICH=ACOS(CX/SORSV)*RADCON
C
C     SKIP RAYTRACE IF PROP LOSS READ IN
      IF(IPOS .EQ. IPOP) GO TO 175
C
      IF (SNPLT.LE.0.0 .AND. OUTPT .GT. 0.0) PRINT 180
C
C
      CS=AVELP(2)
      PHIC=0.00001
C
C     SEARCH FOR MAXIMUM NEAR SURFACE SOUND SPEED
      CM=CS
      DO 40 I=1,NUMV,2
      IF (AVELP(I).GT.3000.0) GO TO 50
      C=AVELP(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=AVELP(NUMV-1)
      CB=AVELP(NUMV)
C
C     OBTAIN LIMITING ANGLE FOR BOTTOM REFLECTIONS
      PHILIM=0.0
      IF (CX.LT.CB) PHILIM=ACOS(CX/CB)
C
C     INITIALIZE PARAMETERS
C
C     PHI LOOP
C
      CALL PRERAY (0,0,0)
      IBB=0
      ICZ=0
C
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 80
      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) GOTO 100


C
C     DRAW TROUGH IN NOISE CURVE NEAR HORIZONTAL IF PHICH .GT. .5
C     AND GET DISTANT SOURCE (HOR) NOISE COMPONENT
```

```
      JCNT=JCNT+1
      I51=JP1+1
      XANG(I51)=-PHICH*.7
      XANG(I51+1)=PHICH*.7
      YDB(I51)=10.*ALOG10(10.**(THRDB/10.)+10.**(HORDB/10.))+100.
      IF(PHICH .LT. .5) YDB(I51)=YDB(JP1)
      YDB(I51+1)=YDB(I51)
      TOTLI=TOTLI+HORZI*2.*PHICH
      JP1=JP1+3
C     INITIALIZE CZ FOLDING RANGE CHECK
      CALL PRERAY (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
      PHI=(PHIC+0.001)*RADCON
      GO TO 70
   90 CALL RAPATH (ICZ,PHIS,DELR)
      IF (ICZ.EQ.1) GO TO 100
      IF (IBB.EQ.1) GO TO 80
      IF (DELR .GT. 1.) PHINC=0.5*PHINC
      GO TO 70
C
  100 CONTINUE
      IF (PHIS.LT.PHILIM) GO TO 70
  110 CONTINUE
C
C     CALCULATE OMNI NOISE LEVEL
C
      IF (TOTLI.LE.0.0) GO TO 171
      TOTLN=10.0*ALOG10(TOTLI)+184.8850
      HORDB=HORDB+100.
      FRE1=FREQ*1000.0
      PRINT 200, DGREH,TOTLN,FRE1,ZX
      CANGL=2.*PHICH
      IF(SHLFS .GT. 0.0 .AND. PHICH .GE. 0.) PRINT 220,HORDB,CANGL
C
C     BYPASS TARGET IF PROP LOSS READ IN
      IF(PTEST.EQ.1.0) GO TO 120
C
C
      IF (ZTG1) 120,130,130
  120 IF (SNPLT.GT.0.0) CALL PLT (PTEST)
      GO TO 150
C
C     TARGET RANGE-DEPTH LOOP
C
  130 NT=ZTGNO
      NR=RGTNO
      HTST=HFLAG
      DO 140 I=1,NR
      DO 140 J=1,NT
      YT=J-1
      YR=I-1
      RTG=RGT+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
      IF (SSPLT.GT.0.0) CALL SSPLOT
C
  160 CONTINUE
      HFLAG=HFLG1
      IF (IPOS.EQ.IPOZ) GO TO 10
C
      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 AUXPR(IPOS,PHICH,HORZI)
      PTEST=1.0
      GO TO 110
C
C
  180 FORMAT (/////57X,'OUTPUT'///24X,3HPHI,8X,4HDPHI,8X,5HMAX R,5X,8HLO
     1SS(DB),6X,5HDB UP,6X,7HDB DOWN,3X,10H1 STER COR/)
  190 FORMAT (' TOTLI ZERO OR NEGATIVE - GO TO NEXT CASE')
  200 FORMAT (//6X,F7.1,' DEG SECTOR LEVEL = ',F7.2,' DB FOR',F6.1,' HZ
     1AT',F7.1,' FT DEPTH'/)
  210 FORMAT (7H FREQ =,F10.4,28HKHZ OUTSIDE 10-500 HZ REGION)
  220 FORMAT (8X,'SOFAR CHANNEL PER STR NOISE LEVEL ='F6.1,' DB FOR'F5.1
     1,36H 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
      FSQ=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(2.3026*FT)
      ALFAT=0.0542*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=FSQ/FT*(0.650531/*FT/(FT+FSQ/FT)+0.026847)

      ALFA=BF1*ALFAT+BF2*ALFAM
      RETURN
      END
```

```
      SUBROUTINE AUXPR(IPOS,PHICH,HORZI)
C
C     THIS SUBROUTINE CALCULATES AMBIENT NOISE WHEN PROP LOSS IS READ
C     IN AND NOT CALCULATED
C
C
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
C
      DATA IPOZ/'PRLOS'/
C
C
C     INITIALIZED PARAMETERS ARE THE FOLLOWING
C
      TOTLI=1.0E-18
      TOTLI=TOTLI+HORZI*2.*PHICH
      JP1=0
      HORDB = 10.*ALOG10(HORZI)+84.8856
      IF (PHICH .LT. .5) GO TO 1
      Q(1)=-PHICH*.7
      Q(2)=-Q(1)
      W(1)=10.*ALOG10(10.**(THRDB/10.)+10.**(HORDB/10.))+100.
      W(2)=W(1)
      XANG(1)=1.
      XANG(2)=1.
      JP1=2
C
    1 CALL READIN(IPOS)
C
C     CALCULATE WIND NOISE DIRECTIONALITY FACTOR DIRS
C
      CX=FUNU(AVELP,ZX,NUMV)
      CS=FUNU(AVELP,ZTG,NUMV)
      COSPH= COS(.01738*APROP(1))*CS/CX
      IF(COSPH.GE.1.)COSPH=1.
      PHI=ACOS(COSPH)
      EXPN=5.729*PHI
      IF(PHI.LT..3491)EXPN=2.0
      DCOEF=2.*FREQ-.02
      IF(FREQ.GT..5)DCOEF=1.0
      DIRS=1.+(SIN(PHI)**EXPN-1.)*(DCOEF)
C
      RI=APROP(3)
      SHI=FUNS(ASHI1,RI,NMS2)
      PRI=APROP(4)
      RECTI=1.0E-18
      I=-1
    4 I=I+1
      NS=2*I+1
      IF(ASHI1(NS).LE.APROP(3)) GO TO 4
      NP=5
```

```
C     SELECT RANGE INTEGRATION INTERVAL
C
   10 IF(APROP(NP)-ASHI1(NS))30,20,40
   20 RTEST=1.0
      NS=NS+2
   30 RIP1=APROP(NP)
      PRIP1=APROP(NP+1)
      SHIP1=FUNS(ASHI1,RIP1,NMS2)
      NP=NP+2
      GO TO 50
   40 RIP1=ASHI1(NS)
      PRIP1=FUNU(APROP,RIP1,NUMP)
      SHIP1=ASHI1(NS+1)
      NS=NS+2
      IF(RTEST.EQ.1.0) NP=NP+2
   50 CONTINUE
C
C     CALCULATE TOTAL SURFACE NOISE INTENSITY DENSITY FUNCTION
C     DNI=A*RANGE+B
C
      RDIF=RIP1-RI
      IF(RDIF.EQ.0.0) GO TO 80
      SDIF=SHIP1-SHI
      A=SDIF/RDIF
      BWIND=WINDI*DIRS
      BSHIP=SHI-RI*A
      B=BWIND+BSHIP
      DNI=SHI+BWIND
      DNIP1=SHIP1+BWIND
C
C     CALCULATE PROP LOSS INTENSITY REDUCTION FACTOR
C     FROM PROP LOSS = E*RANGE + F , WHERE F INCLUDES G THE LOSS
C     DUE TO THE BEAM PATTERN
C
      PDIF=PRIP1-PRI
      E=PDIF/RDIF
      G=FUNU(ARESP,APROP(1),NUMP)
      F=PRI-RI*E-G
      IF(ABS(E) .GE. .0001) GO TO 60
      RECI=6.282*10.**(-.1*F)*(.3333*A*(RIP1**3-RI**3)+.5*B*(RIP1*RIP1
     1-RI*RI))
      GO TO 70
   60 RECPE=10./(E*2.3025)
      RECI=-6.282*RECPE*(10.**(-.1*PRIP1)* DNIP1*(RIP1+RECPE)-10.**
     1(-.1*PRI)*(DNI*(RI+RECPE)))
      IF(ABS(A) .GT. .0001) RECI=RECI-6.282*A*RECPE*RECPE*(10.**(-.1*
     1PRIP1)*(RIP1+2.*RECPE)-10.**(-.1*PRI)*(RI+2.*RECPE))
C
C     CALCULATE LEVEL RECEIVED FROM HORIZ SECTOR AND TEST FOR LAST RANGE
C
   70 RECTI=RECTI+.0175*DGREH*ABS(RECI)+(THRML+BION)*APROP(2)
   80 RI=RIP1



      SHI=SHIP1
      PRI=PRIP1
      IF(NP.LT.NUMP) GO TO 10
C
C     STORE LEVEL AND ANGLE FOR OUTPUT AND GET TOTAL OMNI INTENSITY
```

```
      JP1=JP1+1
      W(JP1)=10.0*ALOG10(RECTI/APROP(2))+184.8856
      Q(JP1)=APROP(1)
      XANG(JP1)=APROP(2)
      TOTLI=TOTLI+RECTI
      IF(IPOS .EQ. IPOZ) GOTO 1
C
C     SORT AND GET MINIMUM LEVEL
C
      JP1M1=JP1-1
  100 DO 110 K=1,JP1M1
      L=K+1
      IF(Q(L).GT.Q(K))GO TO 110
      DUMYQ=Q(L)
      DUMYW=W(L)
      DUMYX=XANG(L)
      Q(L)=Q(K)
      W(L)=W(K)
      XANG(L)=XANG(K)
      Q(K)=DUMYQ
      W(K)=DUMYW
      XANG(K)=DUMYX
  110 CONTINUE
      JP1M1=JP1M1-1
      IF(JP1M1.GE.2)GO TO 100
C
C     PRINT OUT IF NO PLOT REQUIRED
C
      IF(SNPLT.GT.0.0)GO TO 130
      PRINT 200
      DO 120 K=1,JP1
  120 PRINT 210,Q(K),W(K)
      GO TO 150
  130 DO 140 K=1,JP1
  140 W(K)=W(K)-10.*ALOG10(XANG(K))
  150 CONTINUE
  200 FORMAT(//11X,'PHI',4X,'LEVEL (DB)')
  210 FORMAT(F15.1,F10.1)
      RETURN
      END



      SUBROUTINE BIO
C
C     THIS SUBROUTINE COMPUTES THE CONTRIBUTION OF BIOLOGICAL NOISE
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL


     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
```

```
      ACT=ACTIV/5.0
      DO 10 J=1,11
      BB1=ALOG10(FRE3(J))
C
C     B IS THE DAILY FLUCTUATION
C
      B=.00175*(100.-FRE3(J))*SIN(.002618*(HOUR-300.))
      BI01=-26.6*BB1+20.
      BI02=28.*BB1-52.64
   10 DB(J)=-35.4-10.*ALOG10(10.**(.1*BI01)+10.**(.1*BI02))+B*ACT
     1+2.*ACTIV
      CALL BWIDTH (B2)
C
C     CONVERT TO INTENSITY/VERT DEG/HOR DEG
C
      BION=ACT*B2*DGREH*1.5432E-5
C
      RETURN
      END


      SUBROUTINE BWIDTH (DINT)
C
C     THIS SUBROUTINE INTEGRATES THE SIGNAL INTENSITY OVER BANDWIDTH
C     ADD BANDWIDTH RESPONSE TO NOISE SIGNAL
C
      REAL LEVBW(11),MI,MIP1
C
      COMMON /COMV/ ZX,ZTG,RMAX,PH1D,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),YDB(180),TDEG(18
     30),KP1,TRECL,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
C
C
      DINT=0.0
C
C     OBTAIN EFFECTIVE LEVELS
C
      DO 10 I=1,11
   10 LEVBW(I)=DB(I)-BANDL(I)
C
C     INTEGRATE AND CONVERT TO INTENSITIES
C
      DO 30 I=1,10
      FI=FRE3(I)
      FIP1=FRE3(I+1)
      MI=(LEVBW(I+1)-LEVBW(I))/(10.0*ALOG10(FIP1/FI))
      BI=LEVBW(I)-(ALOG10(FI)/ALOG10(FIP1/FI))*(LEVBW(I+1)-LEVBW(I))
      SMB=3.2467E-9*10.**(BI/10.)
      IF (MI.EQ.-1.0) GO TO 20
      MIP1=MI+1.0
      DIN=(SMB/MIP1)*(FIP1**MIP1-FI**MIP1)
      GO TO 30
   20 DIN=SMB*ALOG(FIP1/FI)
   30 DINT=DINT+DIN
```

```
C     NORMALIZE INTENSITY TO ONE HZ
      DINT=DINT/BANDW
C
      RETURN
      END
      SUBROUTINE ERTHC
C
C     THIS SUBROUTINE CORRECTS FOR EARTH CURVATURE EFFECTS
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      DATA RADCON/57.2957795/
      DATA AB/43642464.29E7/,ASQ/43789029.00E7/,BSQ/43496390.14E7/
C
C     STORE ORIGINAL BOTTOM DEPTH FOR PLOT DATA
      ZB1=AVELP(NUMV-1)
C
C     EARTH CURVATURE CORRECTION
C
      JPAIRS=NUMV/2
      ALAT=ALAT/RADCON
      SINL=SIN(ALAT)
      COSL=COS(ALAT)
      SINLQ=SINL*SINL
      COSLQ=COSL*COSL
      ROL=AB/SQRT(ASQ*SINLQ+BSQ*COSLQ)
      DO 10 I=1,JPAIRS
      I2=2*I
      AVELP(I2)=AVELP(I2)*ROL/(ROL-AVELP(I2-1))
      AVELP(I2-1)=AVELP(I2-1)*(1.+(AVELP(I2-1)/(2.*ROL))+((AVELP(I2-1)/R
     1OL)**2.)/3.)
   10 CONTINUE
      VFLAG=1.0
      ALAT=ALAT*RADCON
      RETURN
      END
      FUNCTION FUNS(A,X,N)
C
C     THIS FUNCTION INTERPOLATES THE SHIPPING HISTOGRAM
C
      DIMENSION A(1)
      ILAST=N
      I=1
      IF(X.GT.A(I).AND.X.LE.A(ILAST)) GO TO 10
      FUNS=0.0
      RETURN
   10 I=I+2
      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(1)
      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.LT.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
C     THIS SUBROUTINE COMPUTES ABSORPTION(HK), SPREADING(HS),
C     AND REFRACTION(HR) LOSSES.
C
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
C     THIS SUBROUTINE COMPUTES SURFACE REFLECTION LOSS
C
C     N =NUMBER OF REFLECTIONS
C     NP=PATH TYPE
C
C     NP  PATH      REFL'S
C      1   DU        N-1
C      2   DD         N
C      3   UU         N
C      4   UD        N+1
C      5   DP         0
C      6   SR         1
```

```
      DATA HS/0.5/
C
      GO TO (10,20,20,30,40,50), NP
   10 ENS=N-1
      GO TO 60
   20 ENS=N
      GO TO 60
   30 ENS=N+1
      GO TO 60
   40 ENS=0.0
      GO TO 60
   50 ENS=1.0
C
   60 HSURF=ENS*HS
C
      RETURN
      END
      SUBROUTINE PLT (PTEST)
C
C     THIS SUBROUTINE PLOTS THE DIRECTIONAL AMBIENT NOISE
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARGO,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMX/CX,ZBM,PH
     3IC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,TLEV,T6DP,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


      INTEGER PN
C
      DATA BERNG/270./,PN/0/
C
      CT=CD+80.0
      IBR=BERNG
      IDGR=DGREH
      DBMAX=-1000.
C
      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
C
C     SET UP AND PRINT OUT HEADINGS IF REQUESTED
C
      ENCODE (40,160,CAP1) (TYTLE(I), I=1,8)
      WSP1=WSPD
      FRQ=FREQ*1000.0
      ENCODE(64,220,CAP2)(LOCAT(I),I=1,3),FRQ
      ENCODE(64,230,CAP3)(DATE(I),I=1,2),ZX
      ENCODE(64,240,CAP4) WSP1,TOTLN
      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=1,13)
      PRINT 170
      PRINT 180
   15 CONTINUE
      IF (PN.LE.0) CALL BALLPT ('PEN 2 BLACKS')
      PN=PN+1
C
C     SKIP 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=I51-1
      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=I51,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=I51+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,I51,2
      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,Q(1),W(1),Q(JP1),W(JP1)
C
      I=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-1.0) 90,100,100
  100 L=JP1-I+1
      IF (OUTPT .GT. 0.) PRINT 190,Q(I),W(I),Q(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,-100,0,0,0,0,7.0,5.5)
```

```
      CALL ENDGR (1)
      CALL PHYSOR (2.0,1.5)
      CALL TITLE (1H ,-1,'VERTICAL RECEIVED ANGLE (()DEG())$',100,'NOISE
     1 LEVEL (()DB RE (M)PA /STR HZ())$',100,7.0,4.8)
      CALL HEIGHT (.1)
      CALL ANGLE (90.0)
      CALL MESSAG('2$',100,-.7,3.2)
      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 (Q,W,JP1,0)
C
C     PLOT TARGET LEVELS IF CALLED FOR AND PROP LOSS NOT READ IN
C
      IF(TGDP.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)=YDEG(J)
      Q(I)=TDEG(J)
      W(I-2)=CD
      W(I-1)=TDB(J)
      W(I)=CD

      IF (DBMAX.LT.TDB(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=TGDP
      ENCODE(64,260,CAP5) IZTG1,RTG
      ENCODE(64,270,CAP4) TRECL,TLEV
      ENCODE(40,280,CAP6) DBMAX
      ENCODE(40,290,CAP7)
      CALL HEIGHT (.1)
      CALL MESSAG (CAP7,100,4.7,4.45)
      CALL HEIGHT (.07)
      CALL MESSAG (CAP5,100,4.3,4.25)
      CALL MESSAG (CAP4,100,4.4,4.1)
      CALL MESSAG (CAP6,100,4.4,3.95)
      CALL DASH
      CALL CURVE (Q,W,KP3,0)
      CALL RESET ('DASH')
      CALL RESET ('HEIGHT')
  130 CALL ENDPL (0)
C
      RETURN
C
C     PRINT OUT ANGLE AND LEVEL WHEN PROP LOSS READ IN IF REQUESTED
C
  151 I=0
```

```
  152 I=I+1
      J=JP1+1-I
      IF (OUTPT .GT. 0.) PRINT 190, Q(J),W(J),Q(I),W(I)
      IF(J-I-2) 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,11HNOISE LEVEL,9X,9HD/E ANGLE,5X11HN
     1OISE 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,12A5,A2)
  210 FORMAT (/7X,'   *  DB  RE MICROPASCAL**2/STERADIAN HZ'/1H1)
  220 FORMAT ('LOCATION',4X,3A5,10X,'FREQ (HZ)',F16.1,'$')
  230 FORMAT ('DATE',13X,2A5,10X,'REC DEPTH (FT)',F11.1,'$')
  240 FORMAT ('WIND SPEED (KT) ',F9.1,12X,'SECTOR LEVEL (DB)',F8.1,'$')
  250 FORMAT ('BOTTOM DEPTH (FT)',F8.1,12X,'HOR SEC (DEG)',I5,' AT',I4,'
     1$')
  260 FORMAT ('----',I4,' FT TARGET AT',F7.1,' KYD $')
  270 FORMAT (F7.1,' DB REC FROM',F7.1,' DB SOURCES')
  280 FORMAT (F7.1,' DB MAX ONE DEGREE AVERAGES')
  290 FORMAT ('   TARGET DATA    $')
      END


      SUBROUTINE PRINTS
C
C     THIS SUBROUTINE PRINTS THE INITIAL PARAMETERS
C
      DIMENSION DOUT(24)
C



      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGND,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WIND(,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVELI(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,TLEV,TGOP,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
C
      DATA BLANK/5H
C
C
C     SORT SHIPPING HISTOGRAM ARRAY
C
      I=-1
      K=-1
    1 K=K+2
      I=I+2
      IF(K.GE.NUMS) GO TO 4
      Q(I)=ASHIP(K)
      Q(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
C
      MAX=MAX0(NUMV,NUMR,NUMH,NUMQ,NUMBW)
C
C     PRINT INPUT VARIABLES
C
      PRINT 70
      PRINT 80, FREQ,ZX,ZTG,PHID,DELPH,BNCS,WSPD,DGREH,BERNG,HOUR,ACTIV,
     1RAIN,ALAT,SNPLT,SSPLT,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,RGINC,TARG,
     2TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS
C
C
      PRINT 90
      PRINT 100
C
C     PRINT ARRAYS
C
      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)
C
      RETURN
```

```
   70 FORMAT (////48X,'** INITIAL PARAMETERS **'//)
   80 FORMAT (8X'FREQ  =' F6.3' KHZ'5X'ZX    ='F6.1' FT'6X'ZTG   =' F6.1
     1' FT'6X'PHID  ='F6.1' DEG'5X'DELPH ='F6.1' DEG'/8X'BNCS  ='F6.1,9X
     2'WSPD  ='F6.1' XT '5X'DGREH ='F6.1' DEG'5X'BERNG ='F6.1' DEG'5X'HO
     3UR  ='F7.2/8X'ACTIV ='F6.1,9X'RAIN  ='F6.1' IN/HR'3X'ALAT  ='F6.1'
     4 DEG'5X'SNPLT ='F6.1,9X'SSPLT ='F6.1/8X'HFLAG ='F6.1,9X'ZTG1  ='F6
     5.1' FT'6X'ZTGNO ='F6.1,9X'ZTINC ='F6.1' FT'6X'RGT   ='F6.1' KYD '/
     68X'RGTNO ='F6.1,9X'RGINC ='F6.1' KYD '4X'TARG  ='F6.1,9X'TARG0 ='F
     76.1,9X'TARG1 ='F6.1/8X'TARG2 ='F6.1,9X'TARG3 ='F6.1,9X'SHIPD ='F6.
     81,9X'SHLFR ='F6.1' NMI'5X'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
     1I  SHIPS  KT    FT',8X,'HZ    DB DOWN'/)
  110 FORMAT (F10.1,F8.1)
  120 FORMAT (24A5)
  130 FORMAT (F7.1,2F6.1,F6.0)
  140 FORMAT (F7.1,F6.1,6X,F6.0)
      END

      SUBROUTINE RAPATH (ICZ,PHIS,DELR)
C
C     THIS SUBROUTINE GENERATES RAY PATHS AND CORRESPONDING
C     PROPAGATION LOSSES FOR BB AND CZ MODES.  RAY PATH
C     COMBINATIONS ARE OBTAINED FOR UP TO NMAX BOTTOM
C     REFLECTIONS(OR REFRACTINONS) FOR EACH D/E ANGLE(PHIS).
C
      DIMENSION SX(4), ST(4)
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(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),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      DATA RADCON/57.2957795/
      DATA (SX(I),I=1,4)/-1.0,-1.0,1.0,1.0/
      DATA (ST(I),I=1,4)/-1.0,1.0,-1.0,1.0/
C
C
      COSPHS=COS(PHIS)
      CV=CX/COSPHS
      CALL VERTEX (ZLO,ZHI)
      IF (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 RAYTRC (PHIS,ZX,ZBM,SXB,RXB,DRXB,PHIBOT,GRADB,ZEND)
      BRL=FUNU(AHB,RADCON*PHIBOT,NUMH)
C
C     RAYTRACE FROM SOURCE UP TO SURFACE
      CALL RAYTRC (-PHIS,0.0,ZX,SXS,RXS,DRXS,PHIE,GRADS,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
C     RAYTRACE FROM SURFACE (OR VERTEX DEPTH) DOWN TO TARGET
      CALL RAYTRC (PHIE,ZSURF,ZTG,SST,RST,DRST,PHND,GRADT,ZEND)
C
C     DIRS IS THE NOISE SOURCE DIRECTIVITY
C
      EXPN=5.729*PHND
      IF (PHND.LT..3491) EXPN=2.0
      DIRS=1.+(SIN(PHND)**EXPN-1.)*(2.*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
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
C     MAXIMUM RANGE CHECK
C
      SK=SN+SX(K)*SXS+ST(K)*SST
      DK=DN+SX(K)*DRXS+ST(K)*DRST
C
C     ELIMINATE CAUSTIC BY RESTRICTING DK
      IF (ABS(DK).LE.1.) DK=1.
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
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(PN.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,DK,GRADT,HK)
      HK=HK+HS+FUNU(ARESP,PN,NUMR)
      CALL SUMINT (K,N,NMAX,RK,HK,PHI,DIRS)
   80 IF (K.EQ.6) GO TO 90
C
C     SURFACE REFLECTED PATH
      K=6
      N=NMAX+2
      S=1.0
      PN=-PHIS
      PX=PHIS
      GO TO 70
C
   90 CONTINUE
      DELR=R-RLAST
      RLAST=R
      RETURN
C
      ENTRY PRERAY
      NTST=0
      ITST=1
      RLAST=200.0
      NMAX=BNCS
      PHMAX=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,4HZEND,E12.6//)
      END

      SUBROUTINE RAYTRC (PHIS,ZUP,ZLO,SP,RP,DRDP,PHIEND,GRAD,ZNP1)
C
C
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),ADANF(30),NUMV,NUMH,NUMR,NUMS,NUMBW,NUMP,NUMF/COMCT/CV,TANPHS
C
C
      RP=0.0
      SP=0.0
      DRDP=0.0
      SINPN=SIN(PHIS)
      COSPN=COS(PHIS)
      PHIN=PHIS
      N=1
```

```
C     TEST FOR NEGATIVE PHISTART
      IF (PHIS.LT.0.0) GO TO 20
C
C     PHIS POSITIVE, DOWN-GOING RAY
      ZN=ZUP
   10 NUM=N
      LL=1
      GO TO 40
C
C     PHIS NEGATIVE, UP-GOING RAY
   20 ZN=ZLO
   30 NUM=NUMV-N
      LL=2
C
   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
   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.0.00001) GO TO 80
C
C     VERTICAL PROFILE COMPUTATIONS
      DELRP=DELZ*COSPN/SINPN
      RP=RP+DELRP
      DELSP=DELRP/COSPN
      SP=SP+DELSP
      GO TO 90
C
   80 GRAD=(CNP1-CN)/DELZ
      RHO=CV/GRAD
      DELRP=RHO*(SINPN-SINPN1)
```

```
      RP=RP+DELRP
      DELSP=RHO*(PHIN-PHINP1)
      IF (DELSP.LT.0.0) ITEST=1
      SP=SP+DELSP
C
   90 CONTINUE
      IF (ITEST.NE.0) WRITE (6,160) ZN,ZNP1,CN,CNP1,COSPN,COSPN1,RP,SP
      ITEST=0
C
C     TEST FOR LAST TIME THRU FOR VERTEXING RAY
      IF (ABS(CV-CNP1).LT.0.00001) GO TO 120
C
C     TEST FOR HORIZONTAL ENTRANCE RAY
      IF (ABS(PHIN).LT.0.0001) GO TO 100
      DRDP=DRDP-DELRP/SINPN/SINPN1
      GO TO 110
  100 DRDP=DRDP-RHO/ABS(SINPN1)
  110 CN=CNP1
      ZN=ZNP1
      PHIN=PHINP1
      N=N+2
      SINPN=SINPN1
      COSPN=COSPN1
      IF ((ZNP1.EQ.ZLO).OR.(ZNP1.EQ.ZUP)) GO TO 130
      IF (PHIS) 30,10,10
C
C     VERTEXING RAY - MUST EXIT
  120 CONTINUE
      DRDP=DRDP+RHO/ABS(SINPN)
      PHIEND=0.0
      GO TO 140
  130 PHIEND=ABS(PHINP1)
  140 RP=RP/3000.0
      SP=SP/3000.0
      DRDP=DRDP/3000.0*TANPHS
C
      RETURN
C
  150 WRITE (6,170) ZNP1
C
      RETURN
C
  160 FORMAT (1X2HZN10X4HZNP18X2HCN10X4HCNP18X5HCOSPN7X6HCOSPN16X2HRP10X
     12HSP/8E12.6)
  170 FORMAT (//'ZNP1=ZN='E10.4)
      END

      SUBROUTINE READIN (WORD)
C
C     THIS SUBROUTINE READS THE INPUT PARAMETERS
C
      INTEGER PAUSE,PARAM,HEADER,ENDATA,PRLOS,WORD,BLANK,ASTRSK,DOT,VNAM
     1E,ANAME,SLSH,DATA,EQU
C
      COMMON /COMV/ VRBL(31)/COMA/ARRAY(30,7),NUMA(7)/COMH/IHDR(16)/COMX
     1/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
```

```
      DIMENSION VNAME(31), ANAME(7), DATA(5), IDATA(16), JDATA(81)
      DATA (VNAME(I),I=1,31)/5HZX   ,5HZTG  ,5HRMAX ,5HPHID ,5HDELPH,5HB
     1NCS ,5HOUTPT,5HWSPD ,5HDGREH,5HSNPLT,5HSSPLT,5HALAT ,5HBERNG,5HHOU
     2R ,5HACTIV,5HRAIN ,5HHFLAG,5HZTG1 ,5HZTGNO,5HZTINC,5HRGT  ,5HRGTNO
     3,5HRGINC,5HTARG ,5HTARG0,5HTARG1,5HTARG2,5HTARG3,5HSHIPD,5HSHLFR,
     45HSHLFS/
      DATA NV/31/
      DATA (ANAME(I),I=1,7)/5HAVELP,5HAHB  ,5HARESP,5HASHIP,5HABW  ,5HAP
     1ROP,5HADANF/
      DATA NA/7/
      DATA PAUSE,PARAM,HEADER,ENDATA,PRLOS ,BLANK,ASTRSK,DOT/'PAUSE','PA
     1RAM','HEADE','END-D','PRLOS',' ','*','.'/
      DATA KOMA/','/,SLSH/'/'/,EQU/'='/
      DATA KINN/1/,KOUT/2/
      IF (WORD.NE.PRLOS) WRITE(6,230)
C
C     READ AND PRINT INPUT CARD
   10 READ (5,240) KINN,(IDATA(IX),IX=1,16)
      WRITE (6,240) KOUT,(IDATA(IX),IX=1,16)
      K=1
      DECODE(80,250,IDATA) (JDATA(JX),JX=1,80)
C
C     SEARCH FOR BEGINING OF LABEL
   20 DO 30 J=K,80
      IF (JDATA(J).EQ.KOMA) JDATA(J)=BLANK
      IF (JDATA(J).EQ.SLSH) JDATA(J)=BLANK
      IF (JDATA(J).NE.BLANK) GO TO 40
   30 CONTINUE
      GO TO 10
C
C     FIND THE END OF THE LABEL
   40 DO 50 K=J,80


      IF (JDATA(K).EQ.EQU) GO TO 60
      IF (JDATA(K).EQ.BLANK) GO TO 60
      IF (JDATA(K).EQ.KOMA) GO TO 60
      IF (JDATA(K).EQ.SLSH) GO TO 60
   50 CONTINUE
      GO TO 80
C
C     PACK UP TO FIVE CHARACTERS OF LABEL INTO CONTROL WORD
   60 K5=K
      JDATA(K)=BLANK
      IF (K-J.GT.5) K5=J+4
      DATA (1)=BLANK
      ENCODE(10,250,DATA) (JDATA(JX),JX=J,K5)
      WORD=DATA(1)
      IF (WORD.EQ.PAUSE.OR.WORD.EQ.ENDATA.OR.WORD.EQ.PRLOS) RETURN
      IF (WORD.EQ.HEADER) GO TO 210
      IF (WORD.EQ.PARAM) GO TO 20
      IF (WORD.EQ.ASTRSK) GO TO 200
C
C     SEE IF LABEL IS A PARAM OR ARRAY
      DO 70 I=1,NV
      IF (WORD.EQ.VNAME(I)) 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 (JDATA(J).EQ.BLANK) GO TO 120
  110 CONTINUE
  120 DO 130 K=J,80
      IF (JDATA(K).EQ.KOMA) GO TO 20
      IF (JDATA(K).EQ.SLSH) GO TO 20
      IF (JDATA(K).EQ.EQU) JDATA(K)=BLANK
      IF (JDATA(K).NE.BLANK) GO TO 140
  130 CONTINUE
      VAL=0.0
      GO TO 10
  140 NDOT=0
      DO 150 J=K,80
      IF (JDATA(J).EQ.BLANK) GO TO 160
      IF (JDATA(J).EQ.DOT) NDOT=NDOT+1
      IF (JDATA(J).EQ.KOMA) GO TO 160
      IF (JDATA(J).EQ.SLSH) GO TO 160
  150 CONTINUE
      J=81
  160 KAR=JDATA(J)
      JDATA(J)=BLANK
C
C     INSERT A DECIMAL POINT IF NUMBER HAD NONE
      IF (NDOT.EQ.0) JDATA(J)=DOT
      DATA (1)=BLANK
      DATA (2)=BLANK


      ENCODE(10,250,DATA)(JDATA(JX),JX=K,J)
      JDATA(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     STOR SINGLE VALUE IN THE RIGHT SPOT AND GO BACK FOR MORE IF CARD N
C
  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
C
      IF (I.EQ.1) VFLAG=0.0
      KIND=2
      NX=0
      GO TO 100
```

```
C     UPDATE NUMBER OF ELEMENTS FOR THIS ARRAY AND STORE THE VALUE
  190 NX=NX+1
      ARRAY(NX,I)=VAL
      NUMA(I)=NX
      IF (K.GE.80) GO TO 10
      IF (JDATA(K).EQ.BLANK) GO TO 100
      GO TO 20
  200 IF (KIND.EQ.2) GO TO 100
      GO TO 80
C
C     READ AND STORE THE TITLE INTO THE COMMON AREA
  210 READ (5,240) KINN,(IHDR(IX),IX=1,16)
      WRITE (6,240) KOUT,(IHDR(IX),IX=1,16)
      GO TO 10
C
  220 CALL EXIT
C
  230 FORMAT (SH1//)
  240 FORMAT (A*,16A5)
  250 FORMAT (80A1)
  260 FORMAT (//10X'ERROR IN INPUTS - ',A5)
  270 FORMAT (F10.0)
      END


      SUBROUTINE SCLNCE (TMIN,TMAX,ND,SNMIN,SNMAX,SNINC)
C
C     THIS SUBROUTINE PRODUCES A NICE SET OF SCALE NUMBERS FOR A PLOT AX
C     INPUTS ARE THE DATA MIN 'TMIN',DATA MAX 'TMAX', AND THE REQUIRED N
C     INTERVALS ALONG THE AXIS 'ND'. THE ROUTINE OUTPUTS A NEW MIN 'SNMI
C     MAX 'SNMAX', AND INCREMENT 'SNINC' FOR ND+1 READABLE VALUES
C
      DIMENSION POWTEN(7), TICVAL(8)


      DATA (POWTEN(I),I=1,7)/10.,100.,1000.,10000.,100000.,1000000.,1000
     10000./
C
C     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
C
C     SET UP ROUNDING VALUE
      ROUND=0.01
      ST=TMIN
      IF (ST.LT.0.0) ROUND=ROUND-1.0
C
C     DETERMINE FIRST GUESS AT INCREMENT
      D=(YMAX-TMIN)/DIV
      P=1.0
      IF (D.LT.10.0) GO TO 30
C
C     REDUCE INCREMENT TO RANGE (1 - 10)
      DO 10 I=2,7
      IF (POWTEN(I).GT.D) GO TO 20
   10 CONTINUE
   20 P=POWTEN(I-1)
   30 D=D/P-0.01
```

```
C     FIND FIRST ALLOWABLE TICVAL
      DO 40 I=1,7
      IS=I
      IF (TICVAL(I).GE.D) GO TO 50
   40 CONTINUE
C
C     COMPUTE NEW INCREMENT
   50 D=TICVAL(IS)*P
      ST=D*AINT(ST/D+ROUND)
C
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
C     COMPUTE NEW MIN AND ADJUST
   60 ST=ST-AINT((DIV+(ST-TMAX)/D)/2.0)*D
      IF (ST*TMIN) 70,70,80
   70 ST=0.0
   80 SNMIN=ST
C
C     COMPUTE NEW MAX
      SNMAX=ST+D*DIV
      SNINC=D
      RETURN
      END


      SUBROUTINE SHIPIN (SHIPI)
C
C     THIS SUBROUTINE CONSTRUCTS THE SHIPPING DENSITY NOISE INTENSITY
C     HISTOGRAM
C


      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,NINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      REAL LMULT
C
C
      J=0
      K=NUMS-2
C
      DO 40 I=1,K,2
C
C     INITIALIZE PARAMETERS
C
      LMULT=1.0
      SMULT=1.0
```

```
C     STORE SHIPS AND FIRST RANGE OF RANGE INCREMENT
C
      RANG1=ASHIP(I)
      SHIPS=ASHIP(I+1)
      J=J+2
   10 IF(ASHIP(I+2).GE.0.0) GO TO 30
C
C     CALCULATE INTENSITY MULTIPLICATION FACTORS FOR SHIP SPEED
      AND LENGTH
      IF(ASHIP(I+2).LE.-50.) GO TO 20
      ADSHP=50.*ALOG10(-ASHIP(I+2)/12.)
      SMULT=2.**(ADSHP/3.0103)
      I=I+1
      GO TO 10
   20 ADLNG=20.*ALOG10(-ASHIP(I+2)/300.)
      LMULT=2.**(ADLNG/3.0103)
      I=I+1
      GO TO 10
C
C     CALCULATE AREA AND CONSTRUCT SHIPPING DENSITY NOISE INTENSITY
      HISTOGRAM
   30 RANG2=ASHIP(I+2)
      AREA=.0087266*(RANG2**2-RANG1**2)*DGREH
      DENS=SHIPS*10000./AREA
      ASHI1(J-1)=RANG1*2.
      ASHI1(J)=DENS*SHIPI*SMULT*LMULT
   40 CONTINUE
C
      NMS2=J+1
      ASHI1(J+1)=RANG2*2.
C
      RETURN
C
      END



      SUBROUTINE SSPLOT
C
C     THIS SUBROUTINE WILL PRODUCE A CALCOMP PLOT OF A SOUND SPEED PROFI
C     'DISSPLA'. THE DEPTH VALUES ARE ALONG THE X AXIS AND THE VEL VALUE
C     THE Y AXIS. THE PLOT WILL BE DRAWN ON A 8.5 X 11 INCH PAGE WITH AU
C
      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,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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 NP/100/
C
      NP=NP+1
      NV=NUMV/2
```

```
C     BEGIN PLOT
      CALL BGNPL (NP)
      IF (HFLAG.LT.0.0.OR.SNPLT.GT.0.0) GO TO 10
      READ (5,50) (LOCAT(I),I=1,3)
      READ (5,50) (DATE(I),I=1,2)
   10 CONTINUE
      ENCODE(40, 70,CAP2)(LOCAT(I),I=1,3)
      ENCODE(40, 80,CAP3)(DATE(I),I=1,2)
      CALL TITLE (1H ,-1,0,0,0,0,5.0,3.0)
C
C     FIND RANGE OF SOUND SPEED
      YMIN=6000.0
      YMAX=0.0
      DO 20 I=1,NV
      X(I)=AVEL1(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
C
C     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)
C
C     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)
C
C     SET UP THE REQUIRED ALPHABET
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STANDARD')
      CALL HEIGHT (0.1)
C
      CALL CURVE (X,Y,NV,0)
C
C     MAKE AND LABEL X AXIS

      XTMP=XMIN
      DO 30 I=1,11
      IXTM=XTMP
      ENCODE (10,60,LABEL(13)) IXTM
      LABEL(I)=LABEL(14)
   30 XTMP=XTMP+XINC
      CALL XAXANG (90.)
      CALL XLBAXS (LABEL,1,11,5.0,' $',100,0.0,0.0)
C
C     MAKE AND LABEL Y AXIS
      YTMP=YMN
      DO 40 I=1,6
      IYTM=YTMP
      ENCODE (10,60,LABEL(13)) IYTM
      LABEL(I)=LABEL(14)
   40 YTMP=YTMP+YINC
      CALL YLBAXS (LABEL,1,6,3.0,'(SOUND SPEED) - FT/SEC$',100,0.0,0.0)
      CALL ANGLE (-180.)
      CALL MESSAG ('(DEPTH) - FEET',14,3.0,-0.6)
      CALL ANGLE (90.)
      CALL RESET ('BASALF')
      CALL MESSAG (CAP2,100,-1.25,.45)
      CALL MESSAG (CAP3,100,-1.0,.45)
```

```
C
C     FRAME AND END PLOT
      CALL FRAME
      CALL ENDPL (0)
      RETURN
C
   50 FORMAT (3A5)
   60 FORMAT (I10)
   70 FORMAT ('LOCATION',4X,3A5,'$')
   80 FORMAT ('DATE',13X,2A5,'$')
      END



      SUBROUTINE SUMINT (K,N,NMAX,RK,HK,PHI,DIRS)
C
C     THIS SUBROUTINE COMPUTES THE NOISE INTENSITY ALONG EACH RAY
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      DATA RADCON/57.2957795/
C
C     TEST FOR FIRST BOUNCE
C
      IF (NTST.EQ.1) GO TO 10
      NTST=1
      DOWNI=0.0



      UPI=0.0
   10 ABSFI=ABS(PHINC)
      RG=RK
C
      SHIP1=FUNS(ASHI1,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+HLOS(K,N))
      HLOS(K,N)=HK
      RNG(K,N)=RK
C
C     TEST FOR FIRST TIME THRU
C
      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*.00873*DR*(2.0*RG+DR)
      XZZ=AREA*0.5**(HL/3.0103)
C
C     ASSUME WIND NOISE DIPOLE DIRECTIONALITY PATTERN AT HIGH FREQ
```

```
C
      WRECI=XZ2*WIND1*DIRS
      SRECI=XZ2*SHIP1
      TOTI=WRECI+SRECI
      IF (K.GE. 3) GO TO 20
      DOWNI=DOWNI+TOTI
      GO TO 30
   20 UPI=UPI+TOTI
      PHUP=-PHI
   30 CONTINUE
      IF (K .EQ. 2 .AND. ITST .EQ. -1 .AND. N .EQ. 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)+184.8856
      DBUP=10.0*ALOG10(UPI)+184.6856
C
C     NORMALIZE LEVEL TO ONE STERAD  AND STORE ARRAYS FOR NOISE PLOT
C
      JCNT=JCNT+1
C
C     CALCULATE PER STERADIAN CORRECTION FACTOR
      ADDB=-10.0*ALOG10(ABSFI*COS(PHI/RADCON)*.109662)
      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 .EQ. 2) ITST=-1
      RETURN
C

   90 FORMAT (16X,8F12.3)
      END

      SUBROUTINE SURFI
C
C     THIS SUBROUTINE CALCULATES THE INTENSITIES OF ALL THE SURFACE
C     NOISE GENERATORS
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(30),ADANF(30),NUMV,NUMH
     4,NUMR,NUMS,NUMBW,NUMP,NUMF/COMX/CX,ZBM,PHIC,ALPHAC,BION
      COMMON HLOS(6,60),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
```

```
C
C     WINT, RAINI AND ASHIP(2N) ARE SOUND INTENSITY DENSITIES DUE
C     TO WIND, RAIN AND SHIPS.  (WATTS/M**2)/KYDS**2
C
      DO 10 J=1,11
      BB1=ALOG10(FRE3(J))
   10 DB(J)=BB1*(4.22*BB1-33.4)-10.9
      CALL BWIDTH (THRML)
C
C     ESTABLISH LOWEST THERMAL LEVEL/VERT DEG/HOR DEG
C
      THRML=THRML*DGREH*1.5432E-5
      THRDB=10.0*ALOG10(THRML+BION)+84.8856
C
C     ESTABLISH MINIMUM SCALE CD FOR NOISE PLOT
C     AND CONVERT TO DB/MICROPASCALS
C
      CD=20.
      IF (THRDB.LE.-80.0) CD=10.
      IF (THRDB.LE.-90.0) CD=0.0
      IF (THRDB.LE.-100.0) CD=-10.0
      IF (THRDB.LE.-110.0) CD=-20.0
C
      WINT=0.0
      IF (WSPD.EQ.0.0) GO TO 30
C
C     WMULT IS WIND SPEED DEPENDENCE
C
      WMULT=.065*WSPD**.7
      DO 20 J=1,11
      BB1=ALOG10(FRE3(J))
C     CORW IS THE SLOPE AND LEVEL CORRECTION FOR SURFACE NOISE SPECTRA
C     EXCEPT SHIPPING NOISE
C
      CORW=29.6*10.**(1.43E-5*FRE3(J)**1.54)
      WLEV1=-18.*BB1-4.
      WLEV2=9.66*BB1*BB1-43.99*BB1+23.33
   20 DB(J)=WLEV1+(WLEV2-WLEV1)*WMULT+CORW


      CALL BWIDTH (WINT)
   30 RAINI=0.0
      IF (RAIN.EQ.0.0) GO TO 50
C
C     CALCULATE NOISE DUE TO RAIN
C
      ARAIN=ALOG10(RAIN)
      DO 40 J=1,11
      BB1=ALOG10(FRE3(J))
      CORW=.0667*BB1**4.106+29.64
   40 DB(J)=CORW+5.5*BB1+14.5*ARAIN-49.5
      CALL BWIDTH (RAINI)
   50 WINDI=WINT+RAINI
C
C     CORL IS THE MODEL DISTORTION FACTOR FOR OMNI SOURCES
C
      IF (SHIPD.EQ.0.0) GO TO 90
      DO 60 J=1,11
      BB1=ALOG10(FRE3(J)-2.*SHIPD+12.)
      CORL=14.*FREQ+8.74+4.*SHIPD
      SL1=-1.0*BB1+1.16
```

```
      SL2=3.3*BB1-6.274
      DB(J)=-15.-10.*ALOG10(10.**SL1+10.**SL2)+CORL
      IF(SHLFS .LE. 0.0) DB(J)=DB(J)+5.
   60 CONTINUE
C
      CALL BWIDTH (SHIPI)
   70 CONTINUE
C
C     CONSTRUCT SHIPPING DENSITY NOISE INTENSITY HISTOGRAM
C
      CALL SHIPIN (SHIPI)
C
      RETURN
   90 SHIPI=0.0
      GO TO 70
      END


      SUBROUTINE TARGET
C
C     THIS SUBROUTINE COMPUTES THE DIRECTIONAL SIGNAL
C     LEVEL RECEIVED FROM A TARGET
C
C
      COMMON /COMV/ ZX,ZTG,RMAX,PHID,DELPH,BNCS,OUTPT,WSPD,DGREH,SNPLT,S
     1SPLT,ALAT,BERNG,HOUR,ACTIV,RAIN,HFLAG,ZTG1,ZTGNO,ZTINC,RGT,RGTNO,R
     2GINC,TARG,TARG0,TARG1,TARG2,TARG3,SHIPD,SHLFR,SHLFS/COMA/AVELP(30)
     3,AHB(30),ARESP(30),ASHIP(30),ABW(30),APROP(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),RNG(6,60),XANG(300),YDB(300),JP1,JCNT,WINDI,TOTL
     1I,TOTLN,I51,ITST,NTST,THRML,THRDB,CD,ZB1,VFLAG,BANDL(11),FRE3(11),
     2DB(11),BANDW,LOCAT(3),DATE(2),AVEL1(30),ASHI1(30),TDB(180),TDEG(18
     30),KP1,TRECL,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
C
      DATA RADCON/57.29577/


C
      CX=FUNU(AVELP,ZX,NUMV)
C
      CTG=FUNU(AVELP,TGDP,NUMV)
      PHITG=0.0001
      IF (CX.LE.CTG) PHITG=ACOS(CX/CTG)
      TDEG(1)=90.
      TDB(1)=-300.
      KP1=1
      UP=1.0
      RUN=0.0
      YLAST=0.0
      TRECI=1.0E-30
      PRINT 230
      IF (TARG.LT.0.0) GO TO 20
C
C     CALCULATE BROADBAND TARGET ENERGY
C
      DO 10 J=1,11
      BB1=ALOG10(FRE3(J))
   10 DB(J)=TARG0+TARG1*BB1+TARG2*BB1**2+TARG3*BB1**3
```

```
      CALL BWIDTH (TRGTI)
      GO TO 30
   20 TRGTI=3.2467E-9*10.**(TARGO/10.)
   30 CONTINUE
C
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))
C
   40 PHI1=DELPH/(2.0*RADCON)
      IF (RGT.GE.500.) GO TO 200
      CZ=-1.0
      ITEST=0
      DPHI=-.05
      TINT1=1.0E-35
   50 IR=0
      XTRAB=0.0
C
C     TEST FOR RAY WITHIN ACCEPTABLE ANGULAR LIMITS
C
      IF (PHI1.GT.PHIBM.AND.CZ.GT.0.0) GO TO 180
      IF (PHI1.LT.0.0.OR.PHI1.LT.PHIBM.AND.CZ.LT.0.0) GO TO 200
      COSP1=COS(PHI1)
      CV=CX/COSP1
      CALL VERTEX (ZLO,ZHI)
C
C     TEST FOR RAY UNABLE TO REACH TARGET DEPTH
C
      IF (ZLO.LT.(TGDP+5.).OR.ZHI.GT.(TGDP-5.)) GO TO 160
      TANPHS=TAN(PHI1)
      CALL RAYTRC (-PHI1,0.0,ZX,S1,R1,DRDP1,PHND1,GRAD1,ZEND1)
      CALL RAYTRC (PHND1,ZEND1,TGDP,S2,R2,DRDP2,PHND2,GRAD2,ZEND2)
      CALL RAYTRC (PHI1,ZX,ZBM,S3,R3,DRDP3,PHND3,GRAD3,ZEND3)
C
C     TEST FOR RELATIVE POSITION OF TARGET
C
      IF (TGDP-ZX) 60,60,70


C     TARGET ABOVE RECEIVER
   60 RG1=2.*R2
      RG2=2.*(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.*(R3+R1-R2)
      RG2=2.*R2
      RSUP=R1+R2
      RSDN=R2-R1
      E1=0.0
      E2=1.0
C
C     TEST FOR UP-GOING OR DOWN-GOING RAY
C
```

```
   80 IF (UP) 90,90,100
C     DOWN GOING RAY
   90 RSTRT=RSDN
      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 (ITEST.EQ.0) N=(RTG-RSTRT)/SIZE
      Y0=N
      RNODE=Y0*SIZE+RSTRT
      ITEST=1
C
C     TEST TO GET THE SAME NODE AS FIRST TIME THRU AND LOCATION OF
C     TARGET IN CYCLE
C
      IF (IR) 130,120,140
  120 IF (RNODE+RG1-RTG) 130,130,140
  130 RNOD1=RNODE+RG1
      G1=1.0
      IR=-1
      GO TO 150
  140 RNOD1=RNODE
      G1=0.0
      IR=1
  150 CONTINUE
C
C     TEST FOR RAY WITHIN RANGE INCREMENT
C
      DR2=RNOD1-RTG
      IF (DR2) 160,170,170
  160 PHI1=PHI1+DPHI*(1.0+PHI1*.13*(1.+CZ))
      GO TO 50
C
C     CALCULATE LOSSES
C
  170 CONTINUE

      ITEST=0
      SNOD1=2.*Y0*(S1+S3)+E1*(S1-S2+F1*2.*S3)+E2*(S2+S1*(F2-F1))+2.*G1*(
     1E1*S2+E2*(S3+S1-S2))
      FNOD1=2.*Y0*(DRDP1+DRDP3)+E1*(DRDP1-DRDP2+F1*2.*DRDP3)+E2*(DRDP2+D
     1RDP1*(F2-F1))+2.*G1*(E1*DRDP2+E2*(DRDP3+DRDP1-DRDP2))
      CALL HLOSS (PHND2,RNOD1,SNOD1,FNOD1,GRAD2,HLOS1)
C
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)
```

```
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-CNP1)/(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=(CNP1-CN)/(ZNP1-ZN)
      IF (GRAD.EQ.0.0) GO TO 80


      ZLO=ZN+(CV-CN)/GRAD
      RETURN
   80 ZLO=ZN
      RETURN
C
      END
```

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# Declassified LRAPP Documents

| Report Number | Personal Author | Title | Publication Source (Originator) | Pub. Date | Current Availability | Class. |
|---|---|---|---|---|---|---|
| Unavailable | Brancart, C. P. | TRANSMISSION REPORT, VIBROSEIS CW ACOUSTIC SOURCE, CHURCH ANCHOR EXERCISE, AUGUST AND SEPTEMBER 1973 | B-K Dynamics, Inc. | 730101 | AD0528904 | U |
| Unavailable | Daubin, S. C., et al. | LONG RANGE ACOUSTIC PROPAGATION PROJECT. BLAKE TEST SYNOPSIS REPORT | University of Miami, Rosenstiel School of Marine and Atmospheric Science | 730101 | AD0768995 | U |
| NUSC TR NO. 4457 | King, P. C., et al. | MOORED ACOUSTIC BUOY SYSTEM (MABS): SPECIFICATIONS AND DEPLOYMENTS | Naval Underwater Systems Center | 730105 | AD0756181; ND | U |
| MC-012 | Unavailable | CHURCH GABBRO SYNOPSIS REPORT (U) | Maury Center for Ocean Science | 730210 | ND | U |
| Unavailable | Hecht, R. J., et al. | STATISTICAL ANALYSIS OF OCEAN NOISE | Underwater Systems, Inc. | 730220 | AD0526024 | U |
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