REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

(1)

AD-A230 699

Report Date.
1990

3. Report Type and Dates Covered.
Proceedings

4. Title and Subtitle.
Development of Sensible Acoustic Data Base

5. Funding Numbers.
Program Element No. 62435N
Project No. 3511
Task No. JOV
Accession No. DN25811

6. Author(s).
J. Newcomb and R. A. Wagstaff

DTIC
ELECTE
JAN 15 1991
S B D

7. Performing Organization Name(s) and Address(es).
APL/University of Washington
Seattle, WA 98105

8. Performing Organization Report Number.
PR 90:033:245

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529

10. Sponsoring/Monitoring Agency Report Number.
PR 90:033:245

11. Supplementary Notes.
OCEANS

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract *(Maximum 200 words)*.

Data bases are important in underwater acoustics. They are the means whereby past experience and measured or calculated data can be utilized to predict or improve the performance of existing and planned sonar systems. The success by which this can be done depends, to a large degree, on the format of the data base and the nature of the parameters stored therein. Selecting the parameters or statistics to accumulate and determining the best format for storage is not a simple straightforward task. Examples are given that demonstrate the utility of data bases for which parameters and formats have been chosen to optimize the storage, retrieval, and utilization of the information stored. Utilization by and application to the operational Fleet as well as the R&D community are discussed. This work was supported by funding from the ASW Environmental Acoustic Support (AEAS) Program of the Office of Naval Research and from the Office of Naval Technolgy.

Keywords: → Data bases; Underwater acoustics; Acoustic scattering; Backscattering; Water traffic/ships; Information retrieval; Data storage systems; Ocean surveillance. (mm)

14. Subject Terms.
(U) Acoustic Scattering; (U) Underwater Acoustics; (U) Backscattering

15. Number of Pages.
6

16. Price Code.

17. Security Classification of Report.
Unclassified

18. Security Classification of This Page.
Unclassified

19. Security Classification of Abstract.
Unclassified

20. Limitation of Abstract.
SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

(A)

DEVELOPMENT OF SENSIBLE ACOUSTIC DATA BASES

J. Newcomb and R. A. Wagstaff
Naval Oceanographic and Atmospheric Research Laboratory, SSC, MS 39529

ABSTRACT

Data bases are important in underwater acoustics. They are the means whereby past experience and measured or calculated data can be utilized to predict or improve the performance of existing and planned sonar systems. The success by which this can be done depends, to a large degree, on the format of the data base and the nature of the parameters stored therein. Selecting the parameters or statistics to accumulate and determining the best format for storage is not a simple straightforward task. Examples are given that demonstrate the utility of data bases for which parameters and formats have been chosen to optimize the storage, retrieval, and utilization of the information stored. Utilization by and application to the operational Fleet as well as the R&D community are discussed. This work was supported by funding from the ASW Environmental Acoustic Support (AEAS) Program of the Office of Naval Research and from the Office of Naval Technology.

INTRODUCTION

It is impractical and ofttimes impossible to measure acoustic and environmental parameters whenever the need arises to have the appropriate input for sonar system design and performance estimation, for planning future measurement exercises, or for planning and executing tactical or surveillance ASW missions. The "fall back" position that must be relied on, in most cases, is to utilize data or results that were acquired previously and have been methodically stored in a data base. Such data can be retrieved and utilized with nearly as much confidence as if the data were acquired in real time, provided the salient features of the phenomena being characterized by the stored data are realistically represented by the parameters stored in the data base. Unfortunately, this is not always the case.

This paper will discuss the realism of current shipping surveillance data bases and present an alternate method of storing this information. In addition, a method of storing and presenting the spatial and temporal statistics of the ambient noise field and the merits of these methods will be presented and discussed.

DISCUSSION

Shipping surveillance data are almost always presented and stored as shipping density data, i.e., number of ships per some standard unit of seas surface area. Shipping density may be a reasonable statistic in areas where ships are always present. However, it can be misleading in areas where ships are infrequently found. For example, consider an ocean basin or sea in which the majority of the shipping traffic is near the basin boundaries, and the shipping traffic far from the coasts is relatively sparse. This occurs in most large ocean basins far from the major shipping lanes. Now suppose that the number of shipping surveillance flights conducted was sufficient to provide a reasonably high degree of confidence in the results. Chances are that at one time or another, each area or section will be observed to contain at least one ship, even in the areas where ships are seldom observed. When the shipping densities are calculated, nearly all sections will have nonzero densities, although some densities may be less than one. When these data are used in a model, each "fractional" ship (a density value of less than one) will be interpreted to radiate fractional noise power. Thus, instead of a few ships in a few directions radiating noise, as would probably be the case (see Fig. 1), a large number of fractional ships radiate fractional noise from a large number of locations. The differences between the calculated omnidirectional noise levels in these two approaches may not be significant, but the beam noise data, and thus the ambient noise horizontal and vertical directionalities, will be vastly different (see Fig. 2). In reality, a horizontal line array may be able to "see" between the ships as is illustrated by the solid line in Figure 2. This will not be true in the model when the ships are fractured and spread over many boxes (density case) as is illustrated by the dashed line in Figure 2. The fractional ships may be too numerous for most arrays to "see"between, and incorrect conclusions may be drawn from the modeled results.

An exampies of an alternate method of reporting and storing shipping surveillance data is presented in Figure 3 for Winter 1983. The area in which the shipping surveillance was conducted was divided into sections of 0.5° latitude by 1.0° longitude. Within each section there are two values. The top value is the probability of a section being occupied, and the bottom value is the median number of ships observed given, that the section was occupied.

Reporting the shipping surveillance results as a probability of the box being occupied with the most likely number (median) of ships to be expected when occupied is a better indicator of the actual shipping than shipping density information. However, in the event that a noise model requires density information, an approximation to the density can be obtained by multiplying the median number of ships (value below the line) by the probability of occupation (value above the line). For example, in a case where the numbers of ships observed in a particular unit area of sea surface were 1, 0, 3, 0, and 4 for five observations, the shipping density would be 1.6. The approximation to the shipping density (probability times median) gives 1.8. In another case where there may have been 20 fishing vessels observed only once in 10 observations and none otherwise, both the density and the approximation are 2.0. However, in this latter case, the probability of occupation would only be 0.1. Such a low probability of occupation would flag the median occupation statistic (20) as not being representative. This would probably be sufficient justification to ignore the shipping in that particular section in many modeling applications.

Rather than converting the probability and median shipping results to approximate density, it would make more sense to use only the number of ships in each section for which the probability of occupation is 0.5 or greater. This would alleviate using fractional ships in more locations than the total actual number of ships can occupy. Furthermore, it would still permit the use of a noise model that utilizes a density type number.

Various statistics of the ambient noise field are currently stored in data bases. These statistics include the omnidirectional noise levels and the horizontal directionality of the noise field at various locations. Other statistics just as important for the development of a realistic ambient noise model as well as for specific system performance predictions can also be stored in the data base. In particular, spatial and temporal statistics of the noise field are examples of statistics that are valuable, but the determining the best format for storage is challenging.

The azimuthal anisotropy, (beam-to-beam variability or fine scale spatial structure) of the ambient noise measured by an array can be expressed quantitatively by generating beam noise cumulative distribution function (CDF) plots (see Fig. 4a). These CDF plots are valid only for an array with an aperture (or beamwidth) equal to the array used to obtain the data in the CDF plot and, thus, are of limited value for predicting the performance of an different array in this particular noise field.

One method of presenting and storing these data is by plotting the cumulative distribution functions for various array apertures (derived from the measurement array data) superimposed on one plot, as shown in Figure 4b. Such a collection of curves is called an Azimuthal Anisotropy Cumulative Distribution Function (AACDF) plot. AACDF plots are produced for a single frequency from median beam noise levels.

Because the AACDF plot is generated for a large range of array beamwidths, or apertures, it preserves the spatial variability of the noise field that a horizontal directionality estimate averages out. It is a statistic that characterizes the noise field by emphasizing both the spatial and the temporal influence of the noise field on the array.

AACDF plots can be used in system performance estimation by providing distribution functions of the median beam noise levels. This is done for beamwidths (or noise field sector widths) ranging from 0.5 degrees to 10 degrees. Each point on an AACDF plot corresponds to a half-power beamwidth B (degrees, read along the vertical axis), a percentage of azimuth space S (read along the horizontal axis), and a median noise level L on the beam (read along a constant noise-level curve). The meaning of these three numbers is that a line array with a beamwidth of B degrees will measure median beam noise levels of less than L dB for S percent of azimuth space. It is a statistical measure of the levels and frequencies of occurrence of the high levels of the noise field, of the depths and widths of the low regions, and of the distribution of both high and low regions in space. This information is presented in terms of a parameter that makes sense for a line array: the beamwidth.

The AACDF plots convey a considerable amount of information about the noise sources. The AACDF is valuable for assessing the correctness of the spatial distribution of the noise sources and the received noise levels in noise models. The utility of the AACDF for validating noise models is, perhaps, not as evident as it is for estimating the performance of a towed-array sonar system. One of the first things that is usually done when validating a model, is to compare the measured omnidirectional noise level with the one calculated by the model when the modeled acoustic and noise-source environment are as close to the real ones as possible. Next, a comparison between modeled and measured vertical-array output helps to determine whether the physics of acoustic propagation and noise-source radiation are correctly modeled. Comparisons of modeled and measured horizontal directionality determine the correctness of the gross spatial distributions of the noise sources. For example, if a shipping lane is on one side of a site but modeled on the opposite side, the modeled omnidirectional levels and vertical directionality can be in agreement with measured values, but the horizontal directionality can not. On the other hand, the modeled horizontal directionality can agree with the measured horizontal directionality if the model has (a) the same number of ships as there actually were and with the correct source levels, (b) ten times as many ships in the same general direction but with one tenth the source levels, or (c) one tenth the ships with ten times the source level. However, the AACDFs for modeled and measured results can agree only if the noises from the ships are modeled correctly, i.e., the noise levels and the spacings between the ships in the model are statistically the same as that which existed during the measurement period.

This agreement is necessary because the AACDFs are generated from the outputs of beams of varying widths, some that are narrow enough to fit between ships and others that are not. Only when the azimuthal spacing between ships in the model is statistically equal to that which existed during the measurement will the AACDF curves for the modeled and measured noise environments be similar, i.e. have the same spacing and number of curves; and only when the combination of the average source level and the propagation loss gives the correct received level will the modeled AACDF curves have the same levels as those obtained from the measurements. Hence, the AACDF can be a valuable tool for validating noise models.

Similarly, the temporal variability of the noise field can be quantified with a time history plot and a Temporal Anisotropy Cumulative Distribution Function (TACDF) plot, as shown in Figure 5. For any given time series, the statistical moments (i.e., the mean, standard deviation, skew and kurtosis) can be calculated. But the same time series can be reordered and result in another series with identical statistical moments. The statistical moments are independent of the order of occurrence of the time series. To improve the probability of possible detections, it is advantageous to quantify the order of occurrence of the "holes" in a time series. The TACDF does just that; it preserves this order of occurrence. The TACDF is generated by calculating how often the average level corresponding to a given averaging time remains below a given noise level threshold. These calculations are accumulated and stacked according to increasing averaging time. Constant noise level curves are then drawn on a plot of time window width (time average) versus the percent of time the noise level for a given averaging window remains below the level L. Thus the results can be used to determine the noise level corresponding to a given number of averages and applied to estimating the detection possibilities of various time averaging windows.

Figure 5 presents a time history plot (left) and the corresponding TACDF plot (right) for a given beam of a towed array. Except for a single event, the variability of the time series as shown in the time history plot is moderate, and is reflected in the TACDF plot by the quantity and placement of the contours. As illustrated in the TACDF plot, the low beam noise levels or "noise holes" will be smoothed over as the averaging time window width increases. The corresponding TACDF plot indicates that 40 percent of the time the average power level will increase 4 dB as the size of the average increases from one to three and 6 dB when the size of the average increases from one to ten. This has an important impact on a processor's ability to exploit the temporal noise holes for signal detection and must be carefully considered in the context of S/N enhancement due to increased averaging. The rate that the noise increases will be noise field dependent and, therefore, the change in S/N will depend on the nature of the noise. There is no guarantee that increased averaging will always increase the S/N. In some noise fields, the S/N could decrease.

SUMMARY AND CONCLUSIONS

A method of reporting and storing shipping surveillance information has been developed and presented. The method stores the shipping data in a more realistic manner than simple shipping densities, but is still compatible with models that require shipping density inputs. Methods of reporting and storing the spatial and temporal statistics of the ambient noise field were presented called the Azimuthal Anisotropy Cumulative Distribution Function plot and the Temporal Anisotropy Cumulative Distribution Function plot, respectively. Both methods have the same plot format.

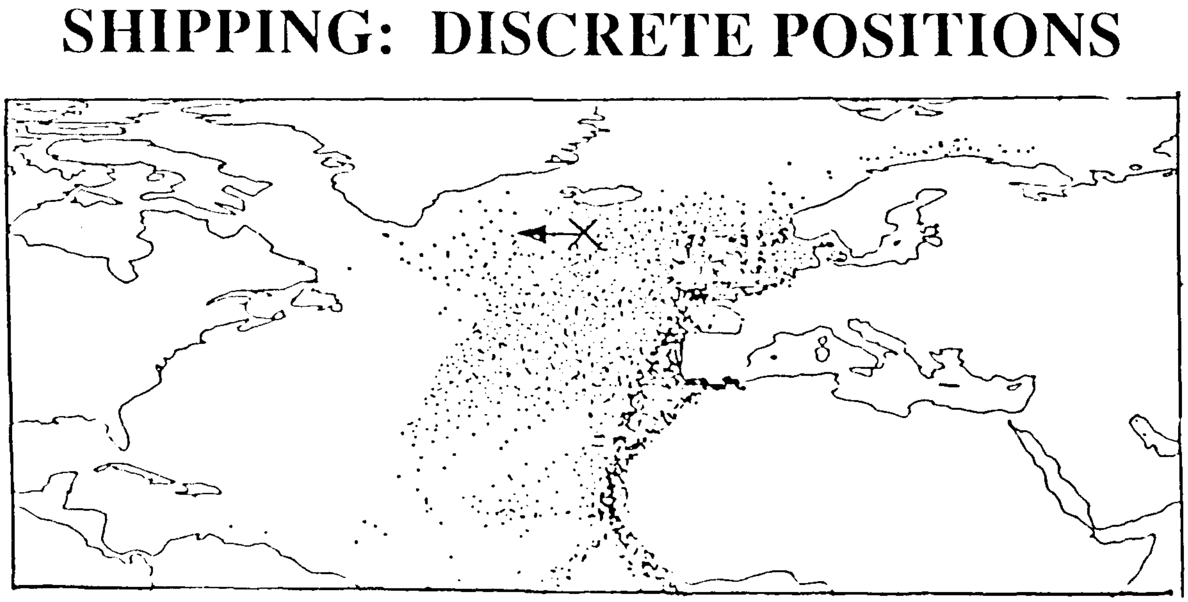

Figure 1. Example of shipping surveillance data plotted in a discrete position format.

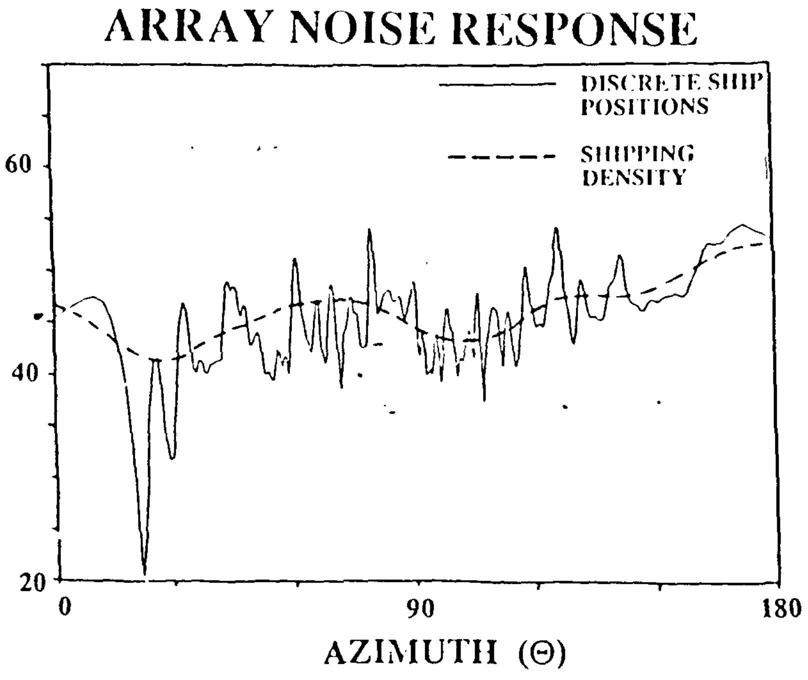

Figure 2. Example of modeled array noise response when discrete shipping data are used (solid line) and when shipping density data are used (dashed line).

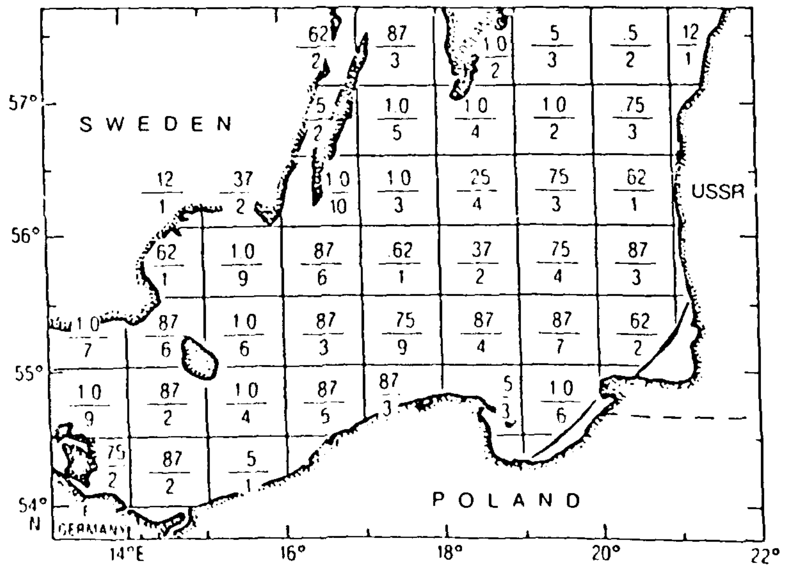

Figure 3. Shipping surveillance data in a format where the probability of a section being occupied (above line) and the median number of ships observed (below line) for occupied sections during summer and winter are presented.

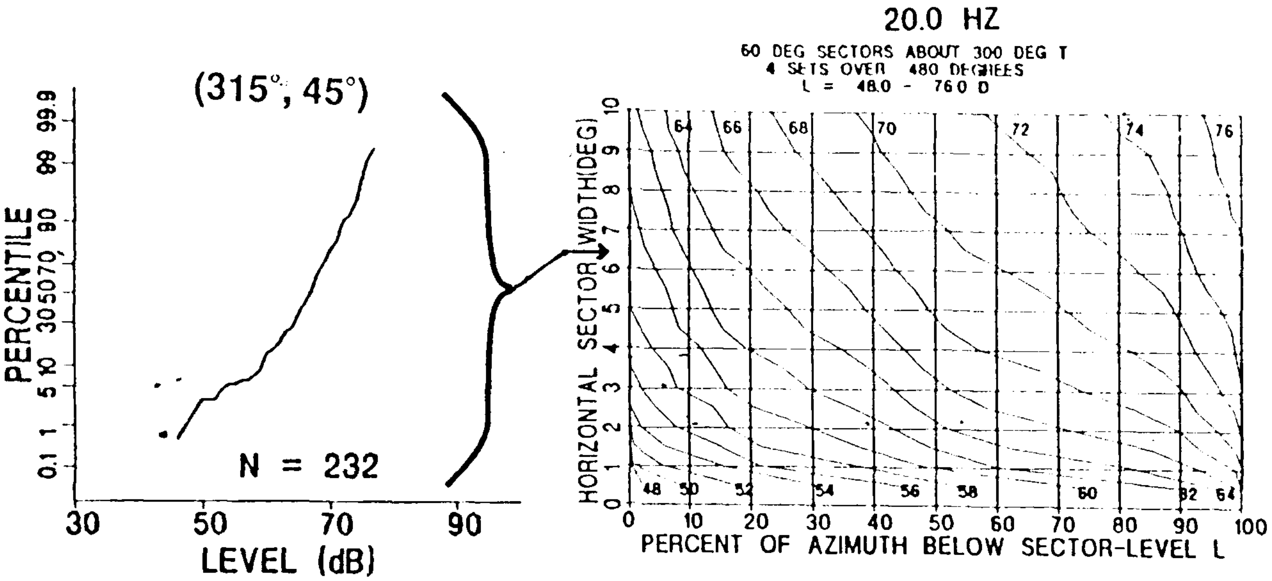

Figure 4. Example of a Cumulative Distribution Function (CDF) plot illustrating its relationship to the Azimuthal Anisotropy Cumulative Distribution Function (AACDF) plot.

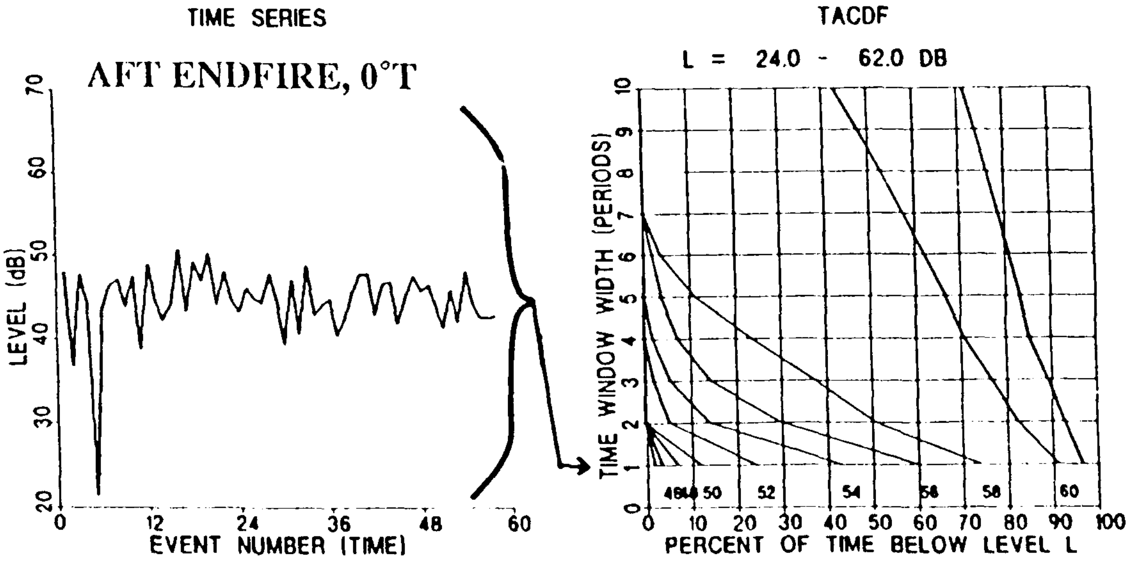

Figure 5. Example of a beam noise time history plot illustrating its relationship to the Temporal Anisotropy Cumulative Distribution Function (TACDF) plot.