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A SUMMARY OF
UNDERWATER ACOUSTIC DATA

PART I
INTRODUCTION

by

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This is Part I of a series of reports intending to summarize the basic information of underwater sound for the practical sonar scientist and naval officer. Subsequent reports in the series will be:

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CONTENTS

A SUMMARY OF UNDERWATER ACOUSTIC DATA

PART I -- INTRODUCTION

INTRODUCTION

Underwater sound was first used by the U.S. Navy in World War I, when simple listening systems (1) were employed to detect and locate German submarines, and echo-ranging was envisaged as a means of detecting slowspeed craft. Since then, and especially under the impetus of World War II, the Navy's use of underwater sound has increased enormously. An idea of the present-day scope of underwater acoustics can be had from Figure 1, which shows the frequency range covered by the various specific Naval applications of underwater sound. It will be seen that these applications cover some six decades in the acoustic spectrum. The present-day sonar platform may be a harbor bottom, a torpedo, a towed body, a submarine, a surface ship, or an aircraft. The uses of underwater sound, once limited to submarine detection, now extend to communication, navigation, ordnance, and countermeasures.

In all these fields there is a group of relationships which basically relate the target (whatever it may be) to the transmitting medium (the sea) and to the equipment being used. These relationships are the so-called sonar equations. Developed during the early part of World War II (2, 3), they permit the working scientist, engineer, or naval officer either to predict the performance of a given acoustic system under specified conditions (4, 5) or to design an optimum system to do a certain task (6, 7). The equations contain a number of basic parameters describing the sound source or target, the medium, and the signal detection system.

The principal task confronting someone interested in performance prediction or in equipment design is to select the values of these parameters that are appropriate to his particular problem. Indeed, the success of his efforts depends on how judiciously he selects these values of the acoustic parameters. In making this selection, the working scientist has been compelled to refer to a rapidly growing and highly scattered body of literature containing the results of wartime and postwar research. The search for representative values is often laborious and sometimes frustrating, and, it is believed, has greatly hindered the use of the sonar equations in helping to solve many problems to which they apply.

In trying to cope with this increasingly chaotic situation, it has been felt that a summary of existing information on the various parameters would be helpful. Such a summary, based on published and unpublished data, should present available information in a convenient form, and be as all-inclusive as possible so as to be applicable to most of the Naval needs indicated in Figure 1.

At the present time, one comprehensive survey of existing data is provided by the NDRC summaries (8) of wartime research and development. Although the volumes are of unquestionable value, the data presented is largely limited to that obtained under NDRC auspices during World War II. Further, the data tends to be wrapped in lengthy and often academic discussion which makes the volumes difficult to use as working references.

With the aim of providing an up-to-date compilation of information, it is intended to present a series of documents, each on one of the several sonar parameters. In this initial volume, a short statement of the equations will be given, the various parameters will be discussed briefly, and an example will be given of the use of the equations in performance prediction.

The sonar equations will be discussed primarily in relation to their application to target detection. Although they are applicable to all underwater sound problems, target detection was originally (4, 5) and has remained (6, 7, 8) the field in which they have found their greatest use. Detection of an underwater target can be accomplished either by listening to the sound it produces or by receiving an echo from it. The first involves one-way and the second two-way transmission. The appropriate equations for these two situations are designated the listening and echo-ranging equations, respectively. In problems other than detection of a target, analysis will indicate whether the listening or echo-ranging equations should be used. Consider, for example, the RAFOS scheme for navigation of submerged submarines. A series of shots are fired at widely distributed points at predetermined times; the submarine's position is determined from the arrival times of the acoustic signals from the shots, at least two of which must be received to provide a "fix." The requirement is that the acoustic signal from the shot source shall be detected in the background at the receiver. This is completely analogous to the passive detection of a submarine, where the acoustic signal is the sound generated by the submarine target. The listening sonar equation would apply to this case, since one-way transmission occurs.

Table 1 lists some of the principal uses of underwater sound together with the applicable sonar equation.

TABLE 1
Applications of Sonar Equations

Use	Sonar Equation	
	Listening	Echo-Ranging
Communications	Underwater telephony Sofar	IFF
Ordnance and countermeasures	Passive homing Acoustic minesweeping	Active homing
Detection of underwater objects (sonar)	Submarine detection (passive) Torpedo detection (passive)	Submarine detection (active) Torpedo detection (active) Mine detection

THE BASIC RELATIONSHIP

The basic detection problem in underwater acoustics is that of detecting a wanted signal in an unwanted background. When we are concerned with detection of targets, * the signal is acoustic energy generated or reflected by the target. The background is

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*A target is any underwater object which generates or reflects a wanted signal.

sometimes noise that is inherent in the transmission medium (ambient noise), noise associated with the equipment being used for detection (self noise), or even noise generated by the target itself, as is sometimes the case when echo-ranging on torpedoes. Also in echo-ranging, the background may be reverberation created by the generated sound.

All detection systems discriminate against the background in favor of the signal, and only a portion of the total background present is effective in obscuring, or masking, the signal. For example, in listening, the ear effectively rejects much of the background in perceiving a narrowband signal, so that only that part of the background near the signal frequency which lies within the so-called "critical band" of the ear serves to mask the signal. This part of the background can be called the masking background. Its level can be defined as the level of the signal which is detectable, on the average, in a certain stated percentage* of a large number of independent trials. That is to say, when detection takes place in this percentage of trials,

$$\text{signal level} = \text{background masking level.}$$

The background masking level may be measured in a given situation, therefore, by injecting an adjustable portion of the signal into the background and observing the signal required for a given probability of signal detection. In general, the background masking will differ for noise and reverberation, and we call the levels for these backgrounds noise masking level and reverberation masking level, respectively.

The above equality is the most general form of the sonar equations. It expresses the basic relationship in the detection problem - that there is a certain signal level which is detectable in a certain fraction of trials in any particular background of noise or reverberation.

THE LISTENING AND ECHO-RANGING SONAR EQUATIONS

In sonar, the signal is either the sound emitted by the target itself, or it is an echo, produced by the target, of purposely-generated sound. In the first case passive detection, or detection by listening, occurs; in the second, active detection, or detection by echo-ranging, takes place. Corresponding to each of these cases are the listening equation and the echo-ranging equation which express the basic relationship stated above in terms of certain fundamental sonar parameters, all of which are in decibel units. These parameters are:

(a) Parameters established by the detection equipment (including the observer)

> Source level (projector)
> Receiving directivity index
> Recognition differential
> Noise level (self noise)

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*This fraction is called the "detection probability" and is usually, but not always, taken to be 50 percent.

(b) Parameters established by the target

>Target strength
>Source level (target)
>Noise level (target noise)

(c) Parameters established by the transmitting medium and its boundaries

>Transmission loss
>Scattering coefficient
>Noise level (ambient noise)

It should be noted that the choice of parameters is to a certain extent arbitrary. Parameters other than these can be chosen which would express the basic detection relationship equally well in terms of underwater sound phenomena. For instance, instead of source level, which specifies the intensity of an emitted sound field, the total acoustic power radiated could be specified together with the transmitting directivity index. Again, instead of target strength, we could use "reflection cross section" of targets as is the practice in radar. Even sound velocity could be specified as a sonar parameter. However, in underwater sound there has grown up a body of usage and custom which now, to a large extent, should determine the choice of parameters and the manner of writing the equations. The above selection of parameters is believed to be in accordance with most accepted usage in underwater sound.

Let us now consider how signal level and background masking level can be expressed in terms of the parameters.

Signal Level

A noisy target generates sound having an intensity specified by the source level of the target. At a distant point, the source level is diminished by the transmission loss. Thus for listening we have, using decibel units,

signal level = source level - transmission loss.

In echo-ranging, the sound projector produces a certain source level. When the sound reaches the target, its level will be reduced by the transmission loss. The target reflects a portion of the incident acoustic energy back toward the projector; the intensity of the reflection is determined by the target strength of the target. In travelling back toward the projector, the intensity level of the reflection is again reduced by the amount of the transmission loss. We thus have*

signal level = source level + target strength - twice
the transmission loss.

Background Masking Level

In underwater sound there are two fundamentally distinct types of unwanted back-grounds. In echo-ranging, reverberation or back scattering of the generated sound often is the background in which the signal is detected. Other types of backgrounds, whatever they may be, will be called noise. It is convenient and customary in the sonar equations to distinguish and treat separately noise and reverberation.

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* The signs in this equation result from the customary definitions of the quantities.

Noise backgrounds can be expressed in terms of an equivalent nondirectional sound field, the intensity level of which is called the noise level. The detection system discriminates against the noise background in two ways. First, the directional properties of the receiving transducer reduce the noise background, as presented to the system, by the amount of the transducer's directivity index, provided that the noise is essentially isotropic, that is, that it has no strong directional components. Second, the remainder of the detection system, including the observer, discriminates against noise in various ways and by means of various techniques. The amount of this discrimination by the electronics and the observer is termed the recognition differential of the system. Together, recognition differential and directivity index form the total discrimination of the detection equipment against noise. The noise level reduced by the amount of this discrimination is the noise masking level, or

noise masking level = noise level - directivity index
+ recognition differential for noise.

When reverberation forms the background, a somewhat similar expression results. At any instant of time, the intensity level of the reverberation, when expressed as the level of an incident plane wave, is called reverberation level. Just as for noise, the detection system has a certain ability to discriminate against reverberation in favor of the signal, expressed as the recognition differential for reverberation, which in general will be different from that for noise. We then have for a reverberation background

reverberation masking level = reverberation level
+ recognition differential for
reverberation*

Reverberation level is not a basic sonar parameter because it varies with time on any one ping, and because it depends on other parameters, such as source level and transmission loss. A more fundamental parameter, to be discussed below, can be termed the scattering coefficient. It expresses the fraction of the incident acoustic energy which is scattered back toward the sound projector by a unit area or volume of the scatterer.

Statement of the Equations

Combining these expressions for signal level and background masking level, the sonar equations may be stated in the compact form given in Table 2.

TABLE 2
The Sonar Equations

Basic Equation:	Signal Level	=	Background Masking Level
Listening Equation:	Source Level - Transmission Loss	=	Noise Level - Directivity Index + Recognition Differential for Noise
Echo-Ranging Equation:			
(1) Noise background:	Source Level + Target Strength - 2 (Transmission Loss)	=	Noise Level - Directivity Index + Recognition Differential for Noise
(2) Reverberation background:	Source Level + Target Strength - 2 (Transmission Loss)	=	Reverberation Level + Recognition Differential for Reverberation

*Directivity index does not appear in the reverberation equation because of the definition of reverberation level in terms of an axial plane wave.

THE SONAR PARAMETERS

Source Level

The source level of a projector or target is the intensity of the sound emitted by the projector or target at a distance of 1 yard from its effective acoustic center,* expressed as spectrum level in db relative to the intensity equivalent of a pressure of 1 dyne/cm^2 in a 1-cps band for a wideband source, and in db above the same reference level for a single frequency source. For a projector the reference point is on the projector's axis; for a target this point is taken in the direction toward the observer.

In most cases, particularly for large targets and projectors, it is obvious that the source level cannot be measured at 1 yard, but must be computed from levels determined at greater distances. Measurements on targets such as ships and submarines usually have been made at distances of the order of 100 yards, and it is customary to express target source levels in terms of a 100-yard reference distance. Since standardization of units is necessary in the sonar equations, 1 yard will be used as the unit of distance. Source levels referred to a distance of 100 yards may be converted to 1-yard levels for use in the equations by applying the transmission loss at 100 yards; usually 20 log r, or 40 db, will be used.

When the total acoustic power output of a projector is given, its source level can be computed from the formula,

$$\text{source level} = 71.6 + 10 \log P + D$$

where P = acoustic power in watts and D = transmitting directivity index. Sometimes the acoustic intensity at a point off the axis of a projector may be required. This level can be determined by reducing the source level by an amount given by the projector's beam pattern.

The source level of a target may occasionally be required for computation of noise level in the echo-ranging equation, as is sometimes the case for active acoustic homing systems in torpedoes.

Directivity Index

As used in the equations, this is the receiving directivity index, that is, that of the receiving transducer used as a hydrophone. It is usually defined, with the transducer used as a projector, as the ratio expressed in db of the intensity at a distant point along the axis of the transducer to that of a nondirectional projector radiating the same total acoustic power. A similar but more complicated definition applies for transducers used as hydrophones; for reciprocal transducers used in the same fashion the two are the same.

Many transducers and arrays are of one of the two simple shapes — the linear array and the circular array — and have beam patterns which can be approximated by those for a circular piston or a line transducer, both in infinite baffles. A nomogram which permits easy computation of the directivity index for these two types of

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* point on a target or projector from which the sound appears to be radiated, when the observed at a great distance.

transducers in terms of their dimensions and frequency is given in Figure 2. The directivity index for the particular type of transducer can be read off the center scale of this diagram as its point of intersection with a straight line joining appropriate points on the frequency and linear-dimension scales. For example, the directivity index of a circular piston of 5 inches diameter at a frequency of 30 kc is 18 db.

The term, directivity index, expresses the degree of discrimination produced by the receiving transducer in favor of the signal against an isotropic background, that is, a nondirectional sound field. Reverberation, however, is not generally isotropic; for reverberation backgrounds it is necessary to use a modified index called the directivity index for reverberation. This quantity will be discussed in connection with reverberation.

Target Strength

Target strength is the ratio, expressed in db, of the intensity of an echo at a distance of 1 yard from the acoustic center of a target to the incident intensity. The target strength of a target will vary with the angle of incidence and the direction relative to the target in which the echo is observed. In all ordinary echo-ranging, the echo is observed in the direction back along the path of the incident sound.

Again it is seldom possible or desirable to make a measurement one yard from the acoustic center of a target. It is therefore necessary to make the echo measurements at greater distances and to compute the target strength by reduction to 1 yard on applying the proper transmission loss.

Transmission Loss

When sound is radiated by a source its intensity decreases with distance as a result of various effects such as spreading and absorption. In general, transmission loss is the decrease in level expressed in db of the acoustic intensity between any two points in the sound field. As used in the sonar equations, the transmission loss is the difference between the level at one yard (the reference distance) from a projector, or from the acoustic center of

Figure 2 - Directivity index nomogram for line and circular piston transducers in an infinite baffle

a target, and the level at the field point. Transmission loss is the only sonar parameter which is primarily range-dependent, and its value in the field at a given time and place largely determines the performance of any sonar system.
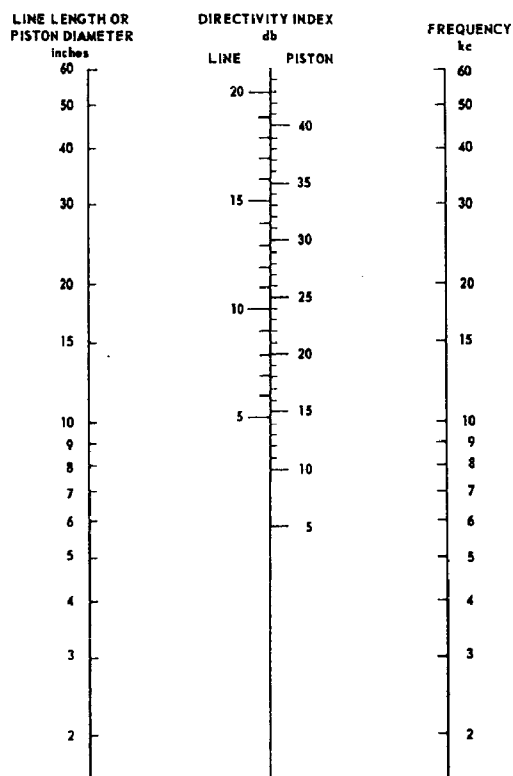
Noise Level

Because of the great difference in their characteristics, it is convenient in the sonar equations to distinguish between "noise" and "reverberation" even though reverberation is strictly a "noise" in that it tends to obscure a wanted signal.

Background noise has many diverse origins. For example, it may even be electronic circuit noise originating in the input stage of an amplifier. Most forms of background noise are essentially isotropic, that is, nondirectional, and for this reason it is customary to define noise level in terms of an equivalent isotropic noise field at the transducer. Measurements of background noise level made with directional hydrophones can be converted to isotropic levels by adding the directivity index. The intensity level of this equivalent isotropic noise field, expressed in db relative to the intensity equivalent of a pressure of one dyne per cm^2 in a frequency band 1 cps wide, is the noise level at the detection system.

Scattering Coefficient

This parameter, in conjunction with others, defines the reverberation level in echo-ranging applications. Reverberation is the result of back-scattering of sound by discontinuities of some sort in the ocean. When these discontinuities are caused by the rough ocean surface or bottom, the scattering is called surface reverberation; when they exist in the body of the ocean itself, volume reverberation is said to occur.

Let us assume that a sound wave is incident upon a unit area of scattering surface or upon the face of a unit cube of a scattering volume of ocean. The scattering coefficient is defined as the ratio, expressed in db, of the sound power scattered by such a unit surface or volume to the power incident upon it when the scattering is assumed to be isotropic. This coefficient divided by 4π for volume scattering, or 2π for surface scattering, is the ratio of the back-scattered intensity at one yard from the unit volume or area, to the incident intensity. As for target strength, the scattering coefficient is more generally a function of the incident angle and the scattering angle. However, interest has hitherto been almost entirely with scattering in the direction back toward the acoustic source.

At a given instant, the reverberation level depends upon the range, the scattering coefficient, the source level, the pinglength, and the transmission loss between the source and the reverberating area or volume. In making a reverberation computation, certain complications arise from the properties of the ocean itself. For example, the transmission loss for reverberation is generally different from that of the echo, because, in general, the scattering area or volume is not located in the same position as the target. Further, the scattering coefficient of a surface varies with angle of incidence and, therefore, with range, while the volume scattering coefficient in the ocean varies with depth. For any given situation, therefore, it is necessary to draw a rough ray diagram to determine all possible sources of reverberation and to make estimates of the scattering coefficient and transmission loss for each such source.

Recognition Differential

A detection system is normally capable of detecting signals when their level is below the background level. As has been stated above, this discrimination arises from the directional properties of the transducer, and from the characteristics of the combination of electronics, method of presentation, and observer being used. The recognition differential defines the second of these contributions; it is the ratio

expressed in db, of the signal level to the background level, measured at the transducer terminals, for an arbitrary detection probability. Normally, this probability is taken at 50 percent; this value will be implied unless otherwise stated. Other detection probabilities are more appropriate, however, for some purposes and may be derived from a "transition curve" in which detection probability is plotted as a function of the signal-to-noise ratio.

In detection, recognition of a signal involves the performance of a human observer. Recognition differential is accordingly in part a psychophysical factor which depends upon such qualities as alertness, fatigue, and mental outlook. Values of this parameter refer to an "ideal" or "optimum" observer who is perfectly trained and alert. Departures from this condition may be called an "observer loss," which apparently has not yet been determined quantitatively although it is of great operational importance.

It is important to note that the recognition differential depends upon the bandwidths of noise and signal presented to the detector. In conformity with the use of a 1-cps bandwidth for noise level and source level, the recognitional differentials for a noise background will be referred to signal and noise in a 1-cps band.

The appendix lists the definitions, units, and points of reference of the various parameters in tabular form.

SOLUTION OF THE EQUATIONS

It is convenient for further discussion to write the sonar equations in symbolic form. We can denote the sonar quantities by the following symbols, which largely follow those used in Reference (8):

L = source level

H = transmission loss for the signal

D = receiving directivity index

M_N = recognition differential for noise

M_R = recognition differential for reverberation

R = reverberation level

T = target strength

N = background noise level

Referring to Table 2, the sonar equations become:

Listening

$$L - H = N + M_N - D$$

Echo-Ranging — Noise Background

$$L - 2H + T = N + M_N - D$$

Echo-Ranging — Reverberation Background

$$L - 2H + T = R + M_R$$

In the last equation, as mentioned above, it is necessary to expand the reverberation level R in terms of the parameter, scattering strength, and certain geometrical and physical factors. Writing

$10 \log m_V$ = scattering coefficient of unit volume,

$10 \log m_S$ = scattering coefficient of unit surface,

J_V = directivity index for volume reverberation,

J_S = directivity index for surface reverberation,

τ = pinglength, in yards

r = range, in yards, and

H_R = transmission loss for reverberation,

it can be shown that for volume reverberation

$$R = L - 2H_R + 10 \log m_V - J_V + 10 \log \tau + 20 \log r$$

and for surface (including bottom) reverberation

$$R = L - 2H_R + 10 \log m_S - J_S + 10 \log \tau + 10 \log r$$

where the last two terms are the volume or area, respectively, from which the reverberation is assumed to come.

Substituting for R, and rearranging, we obtain

Listening

$$L - N + D - M_N = H$$

Echo-Ranging — Noise Background

$$L + T - N + D - M_N = 2H$$

Echo-Ranging — Reverberation Background

Volume Reverberation

$$T - 10 \log m_V + J_V - 10 \log \tau - M_R = 2H - 2H_R + 20 \log r$$

Surface Reverberation

$$T - 10 \log m_S + J_S - 10 \log \tau - M_R = 2H - 2H_R + 10 \log r$$

In this form, the left-hand side of the equations contains only range-independent factors of the medium, equipment, and target. Writing these as Σ_1, Σ_n, Σ_{vr}, and Σ_{sr}, respectively, we have

Listening

$$\Sigma_1 = H$$

Echo-Ranging — Noise Background

$$\Sigma_n = 2H$$

Echo-Ranging — Reverberation Background

Volume Reverberation

$$\Sigma_{vr} = 3H - 2H_R + 20 \log r$$

Surface Reverberation

$$\Sigma_{sr} = 2H - 2H_R + 10 \log r$$

Given the appropriate range-independent parameters and the range dependence of the transmission losses for the signal and reverberation where necessary, we may solve these equations individually for detection range by plotting the right-hand side of the equations as a function of range, and reading off the range at which this equals Σ_1 Σ_n Σ_{vr} Σ_{sr}, as the case may be. In echo-ranging calculations it is usually necessary to compute all three ranges and to choose the least range as the effective range of detection. The result will show whether noise or reverberation forms the limiting background under the chosen conditions. In equipment design, where certain equipment parameters necessary to give a pre-assigned detection range are to be found, the solution is obtained in reverse.

Although the above arrangement of the equations facilitates detection-range computations, it is more meaningful, especially in other applications of the equations, to plot each side of the particular equation arranged in its basic form,

signal level = background masking level,

as a function of range. The detection range for the particular background is then determined as the range at which the two plots intersect. This method has the advantage of showing at a glance whether, in echo-ranging, noise or reverberation is limiting, and presents the manner in which signal and background masking levels vary with range. The method is particularly desirable in the case of a reverberation background where it may not be immediately apparent whether surface, bottom, or volume reverberation is limiting.

EXAMPLE OF USE OF THE EQUATIONS

Let us determine the detection range of an echo-ranging equipment having the following assumed characteristics:

acoustic power output, P . . . . 100 watts

volume reverberation directivity index, J_V . . . . +21 db

pinglength, τ . . . . 58 yd (70 ms)

directivity index, D . . . . +24 db

recognition differential for noise, M_N . . . . +25 db (1-cps band)

recognition differential for reverberation, M_R . . . . . . 0 db

noise level, N . . . . -65 db (1-cps band)

when the characteristics of the target and ocean are as follows:

target strength, T . . . . +15 db

volume scattering coefficient, 10 log m_V . . . . -65 db

transmission loss . . . . H_E H_R

	H_E	H_R
to 1000 yd	68	64
2000 yd	84	75
3000 yd	96	83
4000 yd	107	90
5000 yd	119	96

the conditions being such that surface (including bottom) reverberation can be neglected.

At the limiting range of detection with a given background, noise, or reverberation,

signal level = background masking level.

Now it has been shown that

$$\text{signal level} = L + T - 2H_E ,$$

$$\text{noise masking level} = N - D + M_N ,$$

$$\text{reverberation masking level} = R + M_R$$

$$= L - 2H_R + 10 \log m_V - J_V + 10 \log \tau + 20 \log r + M_R .$$

The source level, L, is given by the equation

$$L = 71.6 + 10 \log P + D$$

$$71.6 + 20 + 24 = 116 \text{ db} .$$

Inserting this value for L and the values of the other parameters in the above equations, we have

$$\text{signal level} \quad = \quad 116 + 15 - 2H_E$$

$$= \quad 131 - 2H_E$$

$$\text{noise masking level} \quad = \quad -65 - 24 + 25$$

$$= \quad -64$$

$$\text{reverberation masking level} \quad = \quad 116 - 2H_R - 65 - 21 + 18 + 20 \log r + 0$$

$$= \quad 48 - 2H_R + 20 \log r$$

Plotting signal level and the noise and reverberation masking levels against range (Figure 3), it is found that equality of the signal level and reverberation masking level occurs at a range of 2000 yards, and that the equality of signal level and noise masking level occurs at a range of 3100 yards. It follows, therefore, that under the given conditions the equipment is reverberation-limited, and that the detection range will be 2000 yards.

CONCLUDING REMARKS

The foregoing example illustrates a graphical solution of the equations employing a set of arbitrary values of the sonar equations. It is seen that the computation of a detection range, or of signal-to-background ratio at some given range is fairly straightforward once the appropriate constants have been chosen. But the sonar engineer or naval officer, in working a practical problem, must start with operational data (such as sea state, target depth, BT condition) rather than with the acoustic parameters. He relies on the results of research and field measurement to provide him with the values of the parameters which apply to his operational situation.

Under a project unofficially termed Project SAD (Summary of Acoustic Data), an attempt is being made to summarize some of the basic information of underwater sound. This information, in the form of seven documents — of which this is the first — will contain numerical data and necessary explanatory material in a form, it is hoped, convenient for
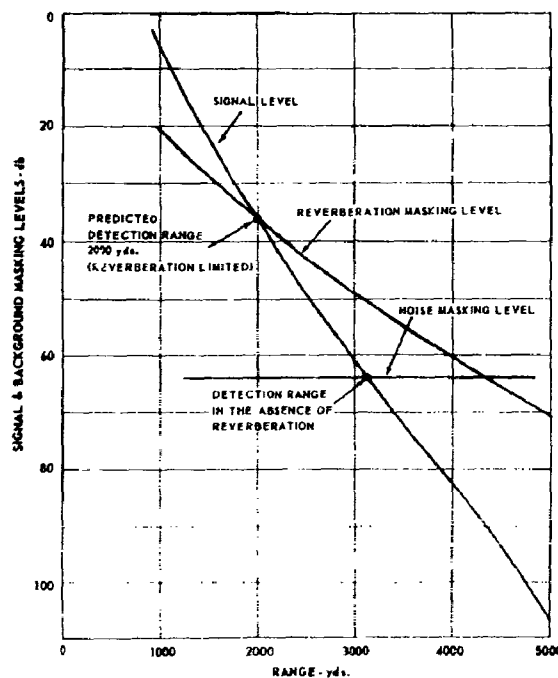

Figure 3 - Solution of the sonar equations for an echo-ranging case

practical use. They will be based on published reports and on up-to-date information obtained on visits to the principal underwater sound laboratories in this country and in the United Kingdom.

It is intended that the summaries be as comprehensive as possible, consistent with early publication. Subsequent revisions to this series may contain the results of new research, inadvertently omitted material, and corrections of errors.

In many of the fields of interest little information is available. The summary documents will try to point out such areas, and so serve as guides to subjects in which more research is needed. Many phenomena in underwater sound are conjectural and existing data are contradictory. It is almost inevitable that in dealing with such subjects the ideas and evaluations of the authors become introduced into the text. A conscientious attempt will be made to point out such cases and to indicate where conjecture and guesswork are necessary.

It is suggested that any shortcomings in the documents to follow can be corrected in future revisions. Constructive criticisms in this regard, as well as the results of new research, are accordingly invited.

The authors wish to express their gratitude to Mr. Wilbert Annis of the Acoustic Branch, ONR, for his interest and encouragement in this work. To the many others in the various laboratories and elsewhere who have given freely of their time and their information, the indebtedness of the authors is gratefully acknowledged.

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APPENDIX
The Sonar Parameters

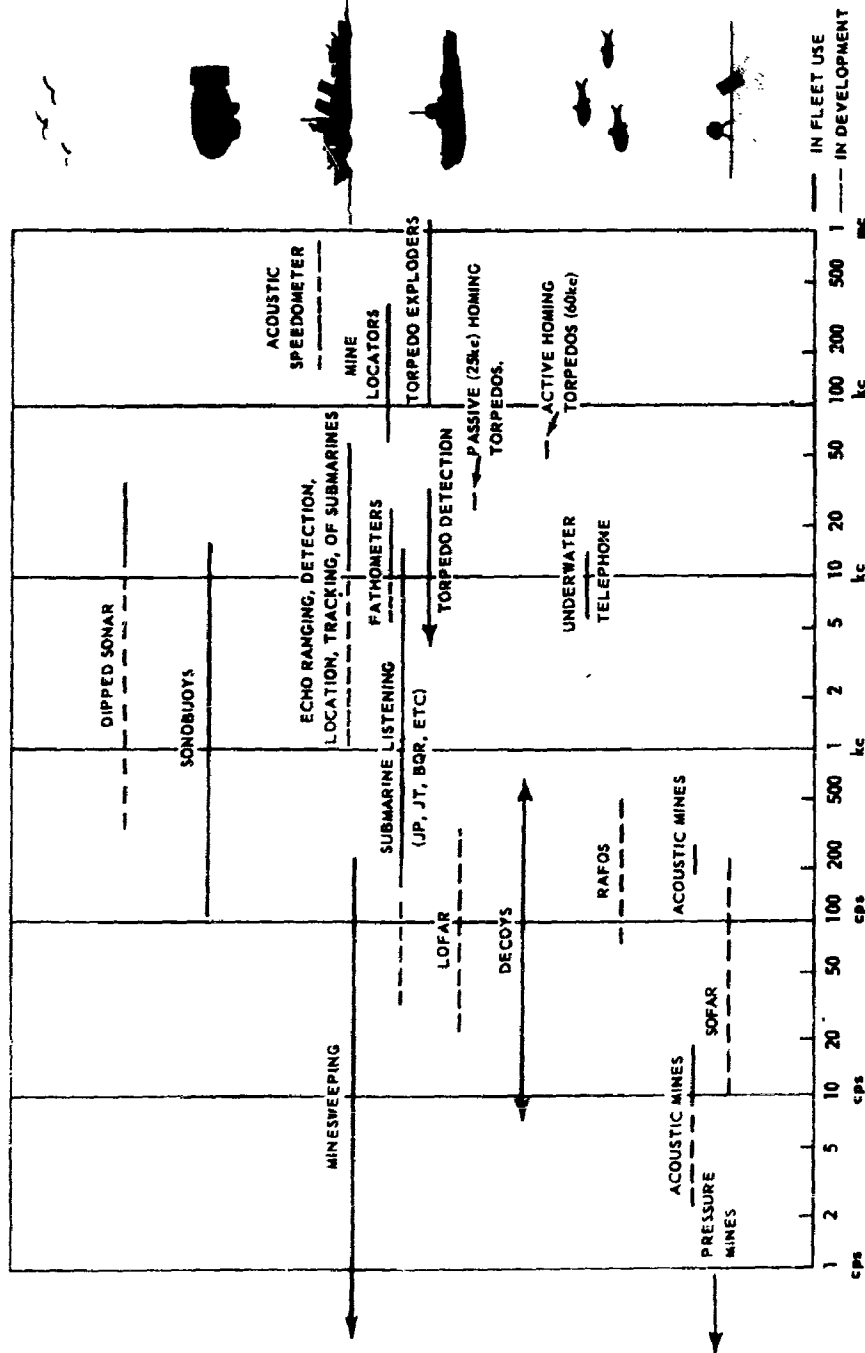| Name	Definition	Units	Point of Reference
Source Level	Intensity level of sound emitted by a projector or target	db above 1 dyne/cm^2 pressure in a 1-cps band for a wideband source	1 yd from the "acoustic center" of the source
Receiving Directivity Index	Ratio of the intensity produced at a point on the axis (when a transducer is used as a projector) to that which would be produced at that point by a nondirectional projector radiating the same total acoustic power	db	Any distant point along the transducer axis
Target Strength	On reflection from a target, the ratio of reflected to incident intensity	db	1 yd from the "acoustic center" of the target
Transmission Loss	Ratio of the intensity of a sound field at unit distance from a source of sound to that at a distant point	db	1 yd from the source
Noise Level (ambient noise or self-noise)	Equivalent isotropic intensity of noise inherent in the ocean (ambient noise) or due to the presence of the equipment (self-noise)	db above 1 dyne/cm^2 pressure in a 1-cps noise band	At receiving transducer
Scattering Coefficient	Ratio of intensity of scattered sound from a unit area (1 sq yd) of surface, or from a unit volume (1 cu yd) of ocean, to the intensity of the incident wave	db	1 yd from the scattering area or volume
Recognition Differential	Ratio of intensities of signal to background when detection probability is 50%	db	Transducer electrical terminals

Figure 1 - Naval uses of the underwater sound spectrum

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IN REPLY REFER TO

5510/1
Ser 93/057
20 Jan 98

From: Chief of Naval Research
To: Commanding Officer, Naval Research Laboratory (1221.1)

Subj: DECLASSIFICATION OF DOCUMENTS

Ref: (a) NRL ltr 5510 Ser 1221.1/S0048 of 25 Feb 97
      (b) NRL memo Ser 7103/713 of 29 Jan 97
      (c) ONR Report "A Summary of Underwater Radiated Noise Data, March 1966"

Encl: (1) ONR Report "A Summary of Underwater Acoustic Data, Part I"   AD- 030 750
      (2) ONR Report "A Summary of Underwater Acoustic Data, Part II"   AD- 039 542
      (3) ONR Report "A Summary of Underwater Acoustic Data, Part III"   AD -039 543
      (4) ONR Report "A Summary of Underwater Acoustic Data, Part IV"   AD- 039 544
      (5) ONR Report "A Summary of Underwater Acoustic Data, Part V"   AD- 105 841
      (6) ONR Report "A Summary of Underwater Acoustic Data, Part VII"   AD- 115 204
      (7) ONR Report "A Summary of Underwater Acoustic Data, Part VIII"   AD- 105 842

1. In response to reference (a), the following information is provided:

   Enclosure (1) was downgraded to UNCLASSIFIED by CNR, 7/29/74;
   Enclosure (2) was downgraded to UNCLASSIFIED by NRL, 12/3/90;
   Enclosure (3) was downgraded to UNCLASSIFIED by CNR, 7/29/74;
   Enclosure (4) was downgraded to UNCLASSIFIED by CNR, 7/29/74;
   Enclosure (5) was downgraded to UNCLASSIFIED by NRL, 12/3/90;
   Enclosure (6) was downgraded to UNCLASSIFIED by CNR, 7/29/74; and
   Enclosure (7) was downgraded to UNCLASSIFIED by CNR, 7/29/74.

Enclosures (1) through (7) have been appropriately stamped with declassification
information and, based on the recommendation contained in reference (b), Distribution
Statement A has been assigned.

AD-396 737

2. To my knowledge, reference (c) has not been previously reviewed for declassification.
Based on our discussions in April 1997, I am still holding it for Dr. Hurdle's comments.

3. Questions may be directed to the undersigned on (703) 696-4619.

Completed
18 apr 2000
B.W.

PEGGY LAMBERT
By direction