ATTENUATION OF LOW FREQUENCY SOUND IN THE SEA: A BIBLIOGRAPHY (U)

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Attenuation of Low Frequency Sound in the Sea: A Bibliography

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26 November 1979

Naval Underwater Systems Center
Newport, Rhode Island • New London, Connecticut

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Preface

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**ATTENUATION OF LOW FREQUENCY SOUND IN THE SEA:**

**BIBLIOGRAPHY**

**Technical document**

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**KEY WORDS**

- Attenuation
- Propagation Loss
- Underwater Acoustics
- Low Frequency Sound

**ABSTRACT**

This technical document contains a listing of all NUSC papers, presentations, and reports concerning the study of the attenuation of low frequency sound in the sea. A short historical narrative is included.
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ATTENUATION OF LOW FREQUENCY SOUND
IN THE SEA, A BIBLIOGRAPHY

INTRODUCTION

The attenuation of sound—the rate at which sound is dissipated during propagation—is one of the fundamental physical parameters of underwater acoustics. It is the relatively low value of attenuation of sound in sea water that makes acoustic systems superior to electromagnetic systems for submarine detection. Hence, attenuation is an essential factor in system design and performance prediction. As a result, attenuation has been the subject of continuing research programs to determine accurate values throughout the oceans of the world for all frequencies of interest.

In this document, the appropriate papers and presentations by members of the staff at the Naval Underwater Systems Center (NUSC) have been listed. These publications are grouped under the following headings:

1. Early work,
2. Thorp era,
3. Modeling results,
4. Scattering, glob theory,
5. Fresh water measurements,
6. Regional variation,
7. Internal waves,
8. pH dependence,
9. Laboratory measurements,
10. Practical formulas, sonar applications, and
11. Implications.

1.0 EARLY WORK

From the introduction of sonar in World War I through World War II and into the early 1950's, primary interest in attenuation was at frequencies above 10 kilocycles (now 10 kilohertz). The principal attenuation mechanism in sea water at these frequencies was found to be an absorption due to a MgSO₄ relaxation process that was proportional to the second power of the frequency.
During this era, NUSC (then the Underwater Sound Laboratory) conducted an extensive acoustic, meteorological, and oceanographic survey (AMOS) to extend results to lower frequencies (below 10,000 Hz). This produced what was called the Marsh-Schulkin formula based on the MgSO₄ absorption. However, some data from at-sea experiments indicated that measured values were greater than those predicted by this formula.

Although there was some controversy, specific experiments were sponsored to measure attenuation at low frequencies. The results suggested further that an anomaly existed. Pertinent papers, presentations, and reports are listed in this section.

1.1 PAPERS


1.2 PRESENTATIONS


1.3 REPORTS


2.0 THORP ERA

In 1965, W. H. Thorp, of NUSC, published a compendium of low-frequency attenuation data which showed conclusively that the measured results were greater than those predicted by the Marsh-Schulkin formula.

As a result, a measurement and analysis program was conducted at NUSC to determine the attenuation of sound in the sea at low frequencies. This effort had three principal goals:

1. To obtain a better analytical expression for the prediction of attenuation (this resulted in the Thorp formula).

2. To determine the variation of attenuation throughout the oceans (a series of experiments were conducted in extremes of temperature and salinity, such as the Red Sea and Hudson Bay).

3. To find the cause of this attenuation anomaly (all data were made readily available to interested members of the scientific community).

As with most fundamental research, the initial objectives were met but unexpected variations were uncovered. Pertinent papers, presentations, and reports are listed in this section.

2.1 PAPERS


2.2 PRESENTATIONS


2.2.2 D. G. Browning, "Finite-Amplitude and Attenuation Research at NUSL," Ultrasonics Symposium, Michigan State University, 1 March 1968.


2.3 REPORTS

2.3.1 D. G. Browning, "Acoustic Attenuation Research at NUSL," NUSL Technical Memorandum No. 2211-196-68, Naval Underwater Systems Center,


3.0 MODELING RESULTS

The measurement of attenuation in the ocean is basically a sound propagation experiment; hence, assumptions have to be made concerning spreading loss, boundary interactions, and diffractive effects. The use of the deep-ocean sound channel simplified the consideration of some of these factors (surface scattering was eliminated, for example), but still some questions persisted.

With the advent of modeling programs for high-speed computers, we found ourselves in the forefront of studying sound-channel propagation predictions in order to understand attenuation experiments. Ironically, it appears that the results of the most sophisticated models tend to verify the simple assumptions that were made initially.

Pertinent papers, presentations, and reports are listed in this section.
3.1 PAPERS


3.2 PRESENTATIONS


3.3 REPORTS


4.0 SCATTERING, GLOB THEORY

As more attenuation experiments were conducted, it became apparent that at the lowest frequencies the measured attenuation was even higher than predicted by the Thorp formula. The additional component appeared to be frequency independent, in contrast to the absorption reactions.

Dr. R. H. Mellen, of NUSC, developed a simple formula based on the multiple scattering of sound, which provided a reasonable fit to the data. The scattering mechanism was due to changes in the physical properties of seawater, referred to as oceanographic inhomogeneities. Conceptually, the ocean can be thought of as composed of patches of water with different sound speeds. Sound would be scattered from these patches, or globs, as it travels through the ocean.

Pertinent papers, presentations, and reports are listed in this section.

4.1 PAPERS


4.2 PRESENTATIONS


4.3 REPORTS


5.0 FRESH-WATER MEASUREMENTS

There were many explanations put forth for the low-frequency attenuation anomaly in sea water. The most likely hypothesis, based on a fit to the data, was a chemical relaxation reaction similar to the MgSO₄ absorption observed at high frequencies.

An indirect way to verify this hypothesis was to make comparative fresh-water measurements (the chemical relaxation mechanism would not be present). Only three lakes in the world had conditions favorable for a low-frequency attenuation measurement:

1. Lake Superior (U.S.A./Canada),
2. Lake Tanganyika (Africa), and
3. Lake Baikal (Russia).
Results were obtained from the first two lakes. Despite a spirited political campaign, it has not been possible to arrange an experiment in the third lake as yet. It was not until further laboratory measurements were made that the data could be fully explained.

Pertinent papers, presentations, and reports are listed in this section.

5.1 PAPERS


5.2 PRESENTATIONS


5.3 REPORTS

6.0 REGIONAL VARIATION

Although the Thorp formula and a simple scattering model gave improved predictions of attenuation, the accumulation of data from throughout the world's oceans showed that significant regional differences occurred. Perhaps most striking was that the anomalous attenuation in the Pacific Ocean was only one-half that measured in the Atlantic Ocean.

Pertinent papers, presentations, and reports are listed in this section.

6.1 PAPERS


6.2 PRESENTATIONS


6.3 REPORTS


7.0 INTERNAL WAVES

Another possible explanation for the scattering component of low frequency attenuation is the interaction with internal waves. The theory of internal waves in the ocean is being developed by Professor W. Munk and his associates at Scripps.

Professor A. C. Kibblewhite (Univ. of Auckland, N. Z.) has shown that the scattering component can have a regional variation.

Comparing the relative merits of the glob theory and internal waves, Mellen and Browning found that attenuation data from surface ducts indirectly would support the internal wave explanation.

Recent work by M. Fecher et al. confirms that regional variation in the scattering component can be explained by internal wave activity.

Pertinent papers and presentations are listed in this section.
7.1 PAPERS


7.2 PRESENTATIONS


8.0 pH DEPENDENCE

A breakthrough that explained all the variation in chemical absorption observed in the ocean was obtained. Drs. Simmons and Fisher, at Scripps, had shown that boron was the key element in the newly-discovered relaxation process. During Simmons' thesis defense, it was suggested that this reaction might be pH dependent. Mellen and Browning followed up on this suggestion and found that all existing data could be related to local values of pH.

Pertinent papers and presentations are listed in this section.

8.1 PAPERS


8.2 PRESENTATIONS


9.0 LABORATORY MEASUREMENTS

Fisher and Simmon's identification of the boron relaxation reaction through laboratory measurements renewed interest in this technique. Mellen, establishing this work at NUSC, discovered a third reaction and is conducting an extensive study of the pH and temperature dependence of the significant reactions in sea water.

Pertinent papers and presentations are listed in this section.

9.1 PAPERS


9.2 PRESENTATIONS

10.0 PRACTICAL FORMULAE, SONAR APPLICATIONS

The end result of this work is to provide the best possible practical formula for the prediction of attenuation at any location in the ocean and for all frequencies.

Whenever a result was obtained that was a significant improvement over existing formulae, it was presented, rather than delay until a 'wrap-up' formula was found.

It now appears that we have a formula to meet the requirements of anti-submarine warfare (ASW); the objective has been met.

Pertinent papers, presentations, and reports are listed in this section.

10.1 PAPERS


10.2 PRESENTATIONS


10.2.4 D. G. Browning, "Recent Measurements in Acoustics," Pres. Submarine Officers' Advanced Course (Class 7604), New London, CT, 5 August 1976.


10.2.7 D. G. Browning, V. P. Simmons, and R. J. Urick (TRACOR), "Practical Values of Low Frequency Attenuation in the Sea," 96th Meeting,
10.3 REPORTS


11.0 IMPLICATIONS

As the mechanisms that cause the attenuation of sound are understood, measured changes in attenuation can be attributed to corresponding chemical and physical changes in the ocean. This implies that acoustic waves can be used to identify water masses and regions of turbulence, and even to estimate the life-support capability of an ocean area. In addition, acoustic data now provide the best available information on the chemical kinetics in sea water.

Pertinent papers and presentations are listed in this section.

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