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D. G. Browning, J. J. Hanrahan, R. J. Christian, and R. H. Mellen (PSI)

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Although initially very high, the rate of spreading loss decreases rapidly with range, while the rate of attenuation remains constant for a given frequency. At increasing ranges the two loss curves cross, with attenuation becoming the dominant mechanism. This results in a "curtain effect" due to rapidly increasing propagation loss. Examples are given of convergence zones obtainable as a function of frequency for various oceans and of the transition between near range and distant ambient noise.

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David G. Browning	(203) 440-4173	3331

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LIMITATIONS OF SOUND PROPAGATION IN THE OCEAN: THE CURTAIN EFFECT

D.G. BROWNING, J.J. HANRAHAN, R.J. CHRISTIAN
NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON, CT 06320

R.H. MELLEN
PSI-MARINE SCIENCES
NEW LONDON, CT 06320

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VIEWGRAPH 1

In the age of super computers, we tend to forget that, in many ways, underwater acoustics is a simple science and that meaningful estimates of propagation characteristics can be made relatively easily. A classic example of this is the article "Approximate Ray Angle Diagram" by Henry Cox, which appeared in the February 1977 issue of the Journal of the Acoustical Society of America, vol. 61, no. 2. Similarly, in this paper we will discuss the curtain effect in underwater sound and present a possible way for its simple estimation.

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5 March 1987

Limitations of Sound Propagation in the Ocean: The Curtain Effect

A Paper Presented at the 112th Meeting of the Acoustical Society of America 8-12 December 1986, Anaheim, California

David G. Browning
John J. Hanrahan
Raymond J. Christian
Surface Ship Sonar Department

Robert H. Mellen
PSI-Marine Sciences

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

PREFACE

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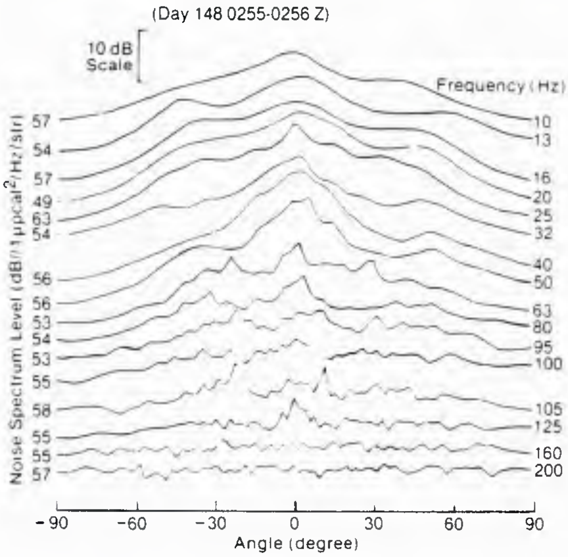
REVIEWED AND APPROVED: 5 March 1987

W. A. VON WINKLE
ASSOCIATE TECHNICAL DIRECTOR FOR
RESEARCH AND TECHNOLOGY

The authors of this report are located at the New London Laboratory, Naval Underwater Systems Center, New London, CT, and PSI–Marine Sciences, New London, CT.

LOW FREQUENCY (LF) DOMAIN VERTICAL NOISE DIRECTIONALITY SOUTH PACIFIC 10-200 Hz (BANNISTER*)



*NUSC TECHNICAL DOC. 6611, 21 JANUARY 1982

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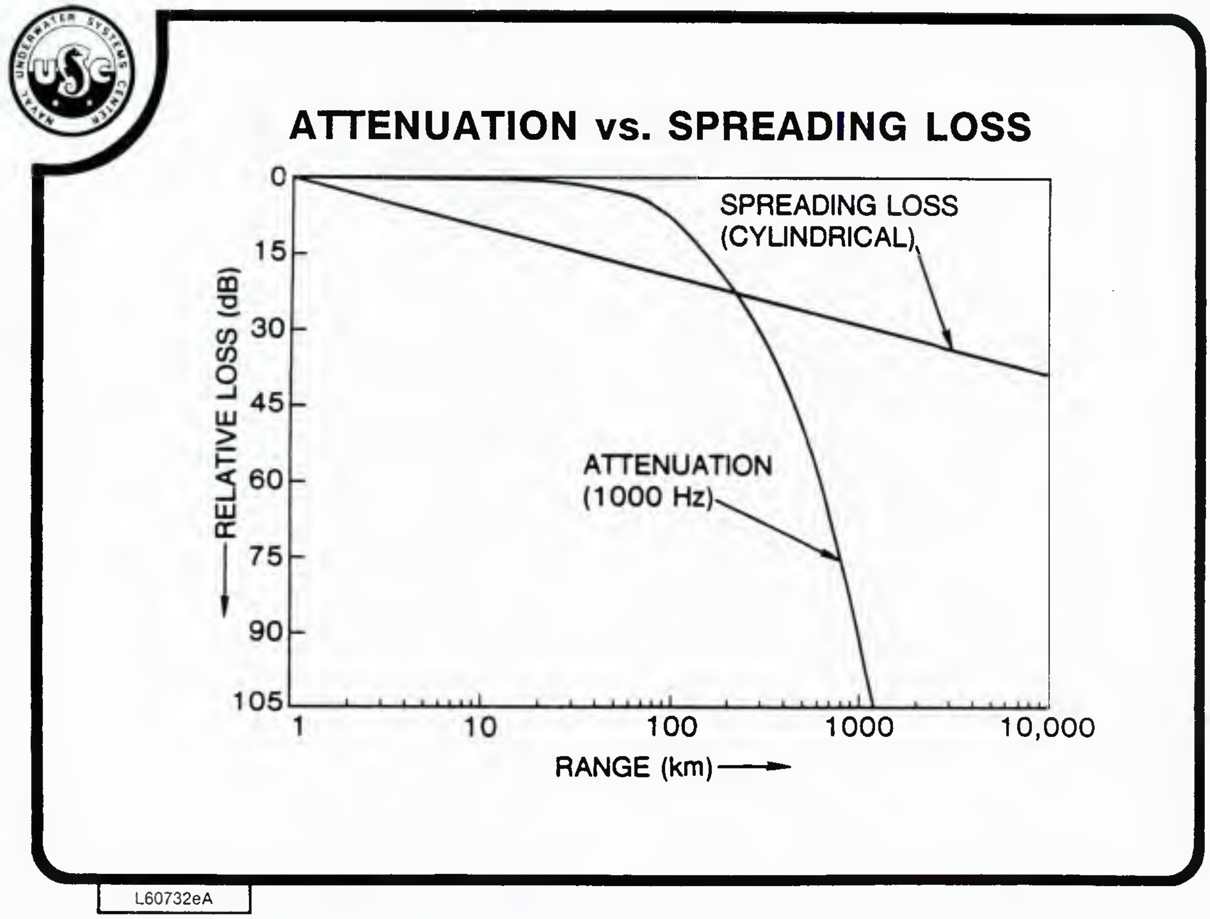
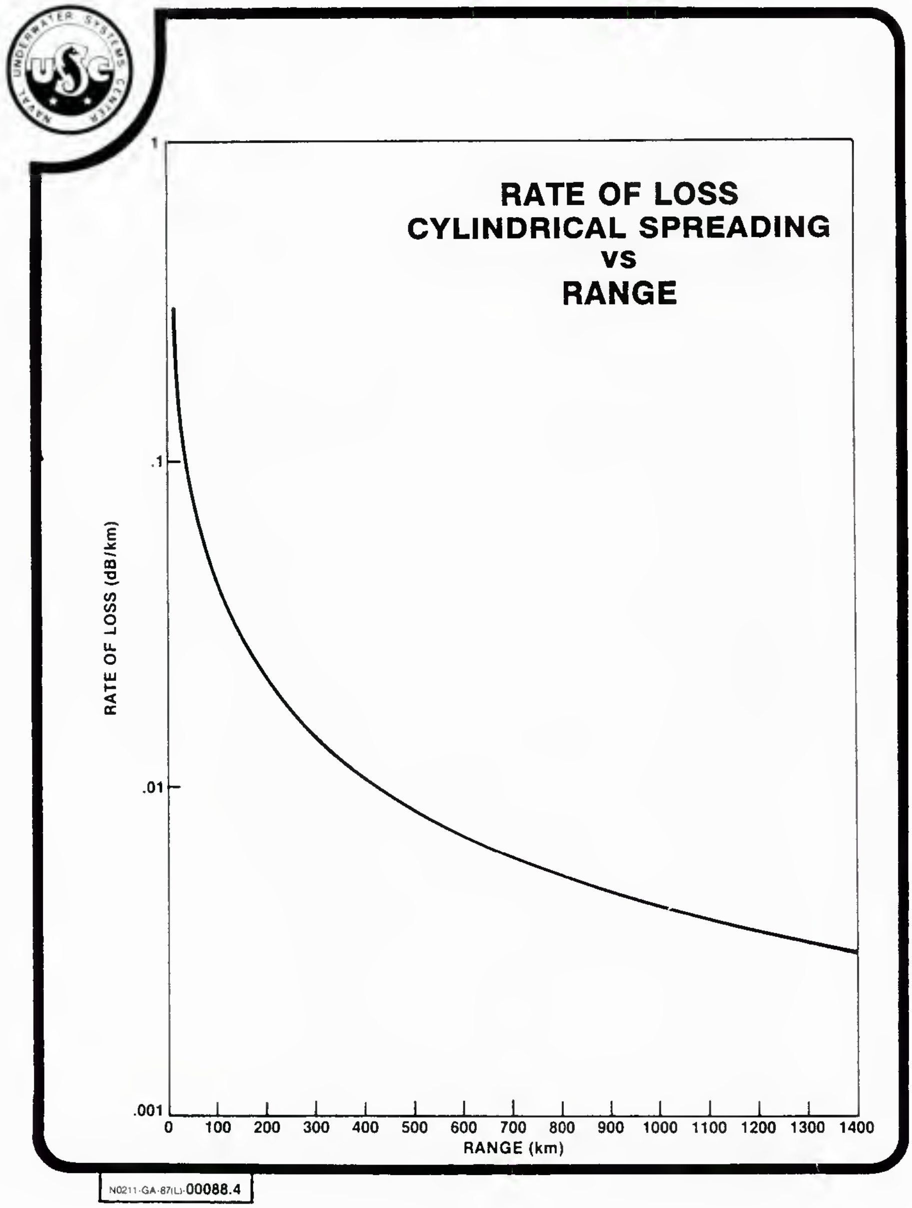
VIEWGRAPH 2

An example of the curtain effect, which we define as a rapid increase in propagation loss due to attenuation, is found in the vertical directivity of ambient noise. At low frequencies (starting at the top) we see a peak at 0 degrees (horizontal) corresponding to noise arriving from long distances. In the frequency range 100-to-200 Hz this rapidly changes, that is, the curtain is coming down so that at 200 Hz we have a relatively uniform contribution at all angles, corresponding to short distances.



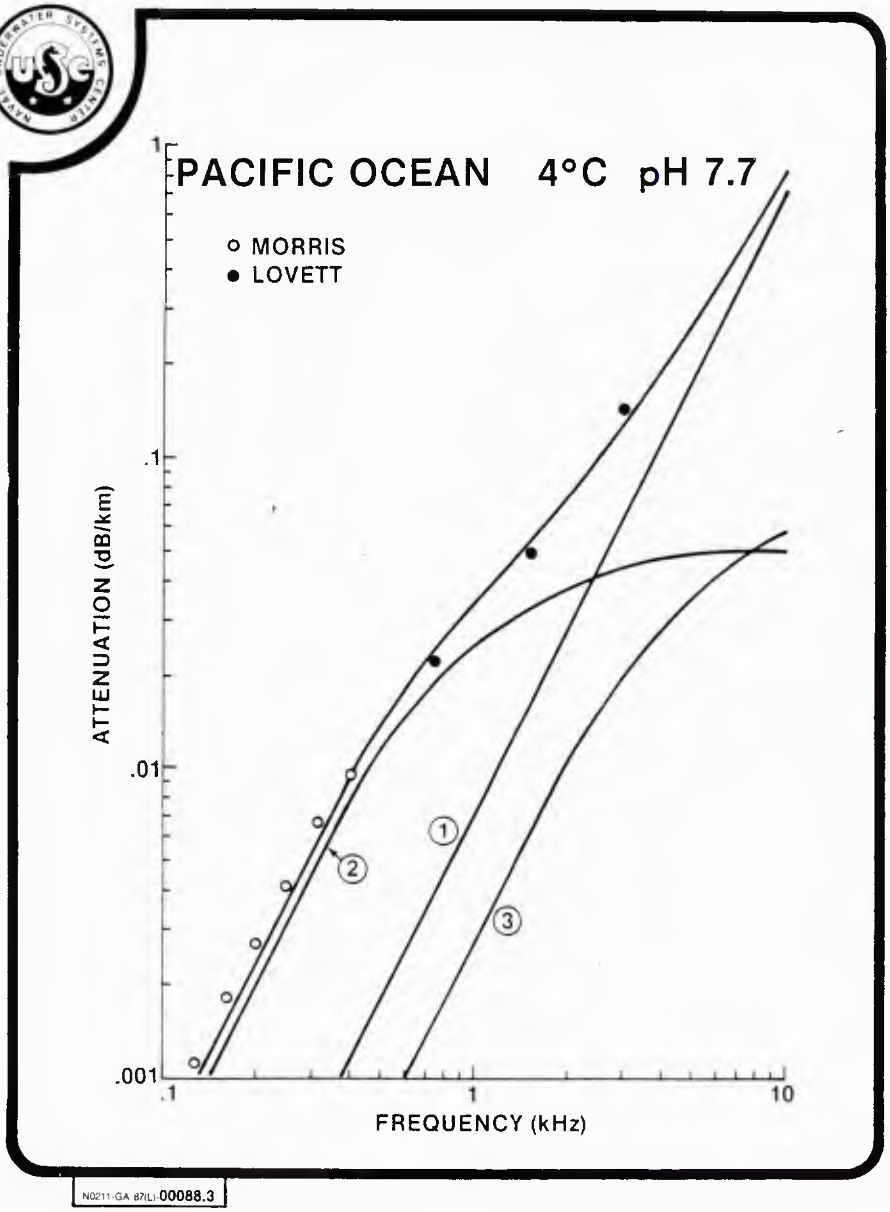
VIEWGRAPH 3

This curtain effect can be illustrated by comparing spreading loss and attenuation loss with range. You can see that when the attenuation loss becomes dominant, the propagation loss increases rapidly, and, for practical purposes, this limits the range that can be obtained.



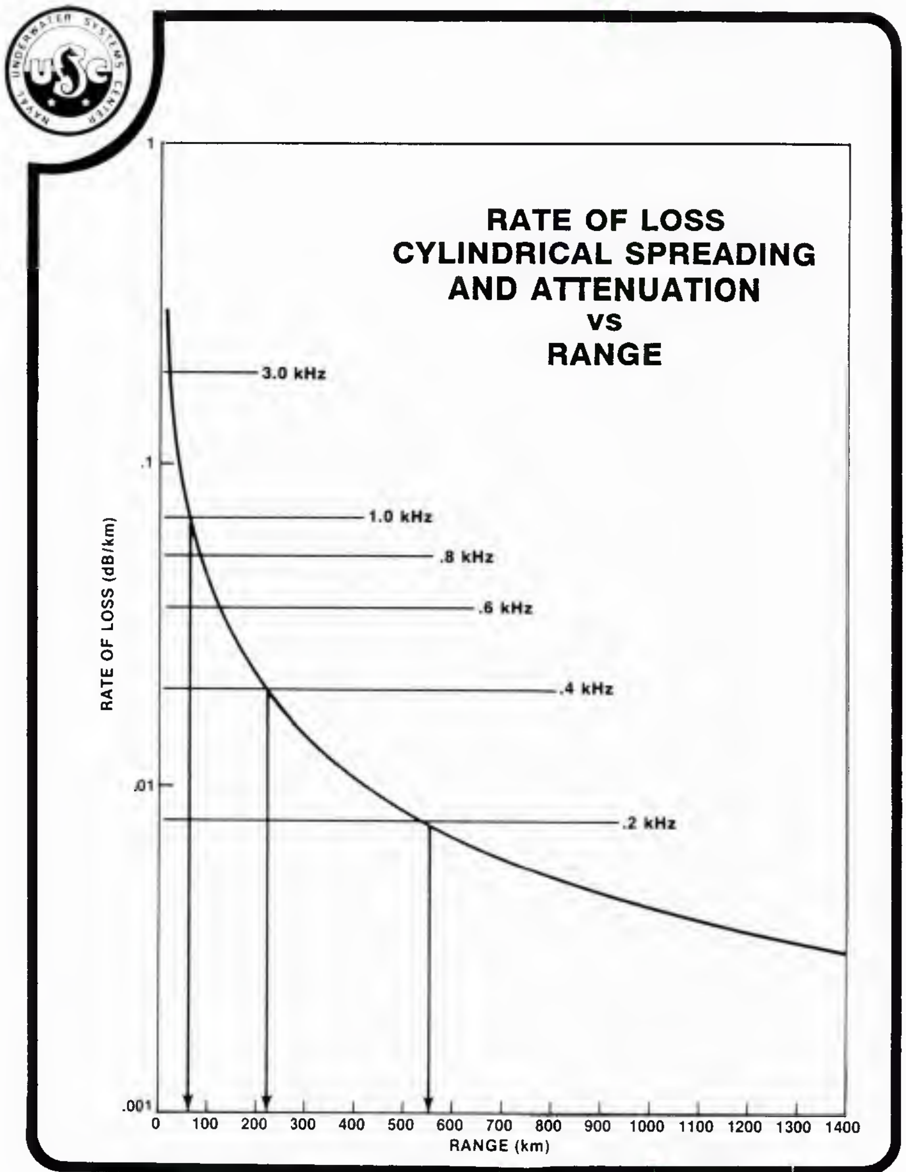
VIEWGRAPH 4

We tried various ways of comparing these two components and we found the rate of loss to be the most enlightening. If you plot the rate of loss for cylindrical spreading -- our old standard of 3 dB per distance doubled -- versus a linear range scale, you can see that the initially high values rapidly decrease with range reaching an asymptotic value.



VIEWGRAPH 5

We know the value of attenuation quite well based on a three-component relaxation model for any frequency of interest. Since attenuation is a rate of loss by definition it will be constant with range for a given frequency. (The three attenuation components are ① magnesium sulphate, ② boric acid, and ③ magnesium carbonate.)



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VIEWGRAPH 6

We now plot the rate of loss for both cylindrical spreading and attenuation to determine the crossover ranges that should be qualitatively indicative of the ranges that can be obtained. Attenuation values for 1 kHz and above crossover in a region with a high rate of spreading loss. The corresponding range is of the order of a convergence zone (2-way) and is relatively insensitive to frequency.

From 1 kHz down to approximately 200 Hz, there is a rapidly changing region with a similar increase in range. Below 200 Hz the rate of loss curve is flattening out so that the crossover points will occur at very long ranges.

RATE-OF-LOSS TYPICAL CROSS-OVER RANGES (NORTH ATLANTIC)

f (kHz)	Rc (km)
5.0	41
3.0	44
1.0	79
0.3	478
0.1	3984

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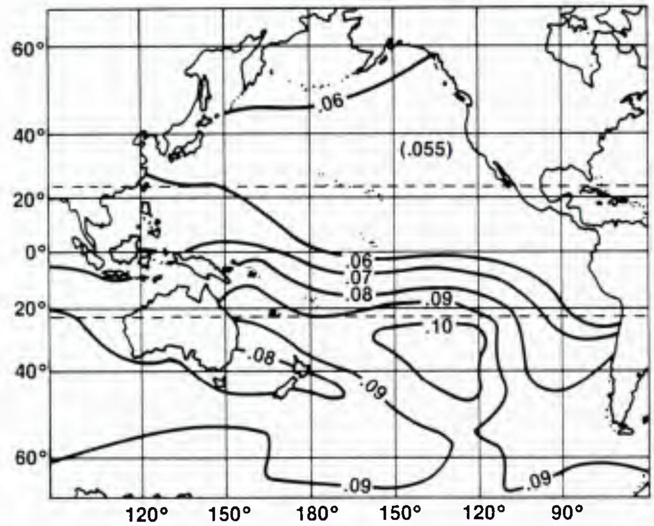
VIEWGRAPH 7

We can obtain an analytic expression for the crossover ranges by equating the attenuation formula to that for the rate of spreading loss.

Typical results for the North Atlantic illustrate the behavior mentioned previously. Between 5 and 3 kHz there is not much change and the range is the order of a convergence zone. At 1 kHz the range is approximately doubled to perhaps two convergence zones.

At 300 Hz the curtain is certainly starting to rise, the crossover range is an order of magnitude greater than at the higher frequencies.

Finally, at 100 Hz we can see the ocean basin size range that is responsible for the low-angle peak in the vertical distribution of ambient noise.



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VIEWGRAPH 8

As the relative attenuation contours first presented by Jack Lovett* of NOSC illustrate, attenuation below 10 kHz can vary regionally. How sensitive will the crossover ranges be to the regional variation of attenuation?

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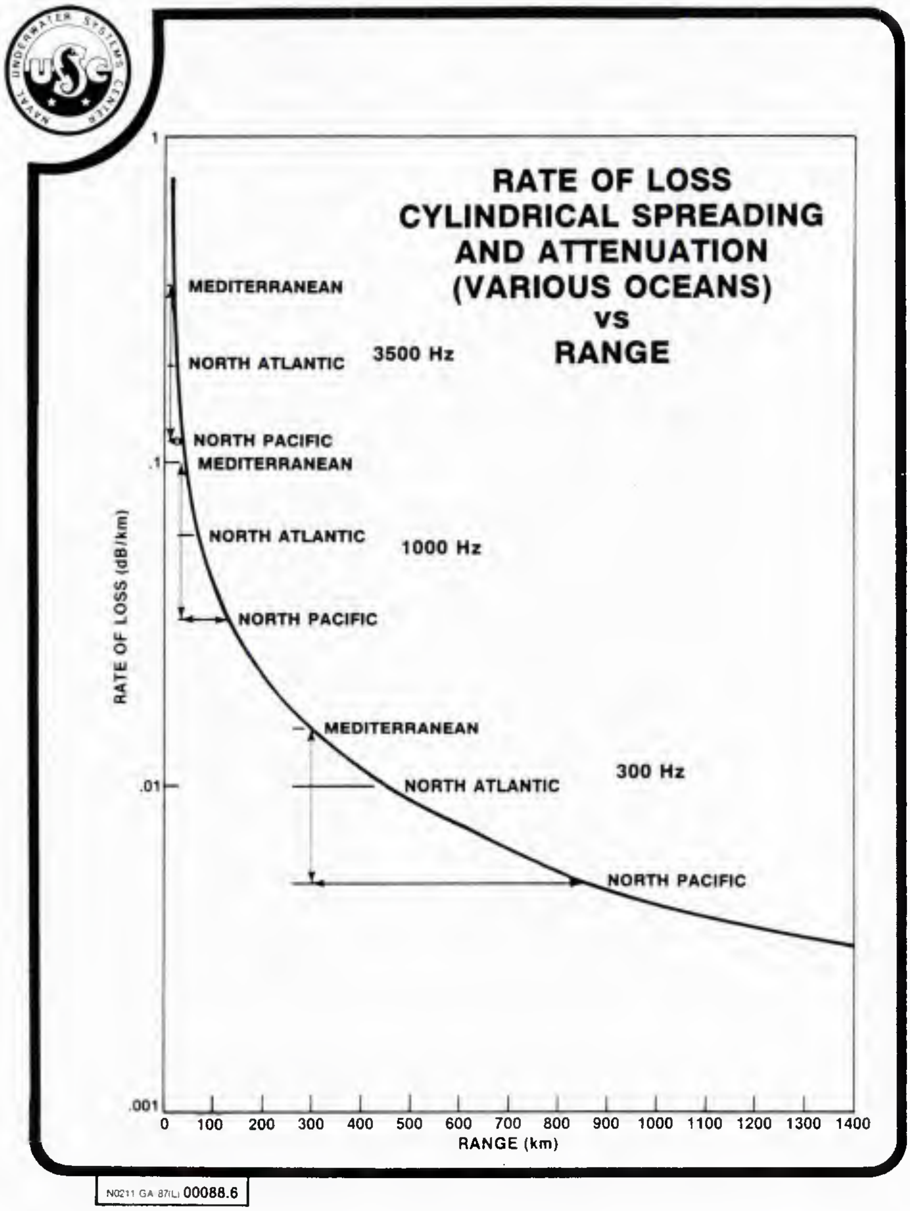
*J. R. Lovett, "Geographic Variation of Low-Frequency Sound Absorption in the Atlantic, Indian, and Pacific Oceans," Journal of the Acoustical Society of America, vol. 67, no. 1, 1980, pp. 338-340.



VIEWGRAPH 9

If we compare attenuation values for three typical areas -- the Mediterranean Sea (relatively high attenuation), the North Atlantic (average, basis for the Thorp formula), and the North Pacific (low attenuation) -- we again see some significant changes over the frequency range.

At the higher frequency the range of attenuation values doesn't result in a meaningful change in range. However, at the middle frequency chosen there starts to be a significant change in range especially for the North Pacific. Finally, at the lowest frequency there is a large change in range.

CONCLUSIONS

- CURTAIN EFFECT WHEN ATTENUATION LOSS DOMINATES
- SIMPLE ANALYSIS FROM RATE-OF-LOSS COMPARISON
- SIGNIFICANT RANGE VARIATION WITH FREQUENCY AND LOCATION

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VIEWGRAPH 10

We can summarize as follows:

- A curtain effect exists when attenuation loss dominates the rate of spreading loss.
- A simple comparison of attenuation and rate of spreading loss gives insight, if only on a qualitative basis, of possible propagation ranges.
- This basic approach also demonstrates the variation that occurs over realistic frequency and attenuation ranges.
- Realizing the pitfalls, we believe this is an interesting concept.

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