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MODELLING OF BOTTOM REVERBERATION IN THE WEST COAST SHELF AREAS

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ABSTRACT

A knowledge of the characteristics of sea reverberation is essential to sonar designers as well as to the users in estimating the interference level and the detection ranges of the sonar. A beginning has been made in this country to estimate the bottom reverberation in the coastal waters of the West Coast. The paper describes the results of the experimental work done in this field as well as a model of the bottom reverberation which can be used for estimating the reverberation levels.

Key-words: Reverberation, West Coast, India.

Sonar systems used in Naval ships for submarine detection or in fishing trawlers for fish detection, use acoustic waves at frequencies of the order of a few kilohertz. The range of detection of the target by the system operating in deep waters is determined when the returning echo signal from that range is just masked by the ambient noise (self noise of ship or sea noise) whereas in shallow waters, the masking noise is set by the reverberation level. The study of reverberation in the sea — both by field measurements and in theory is thus of great significance to the sonar design engineers, as well as to the users. The objective is to establish a reverberation model which will help to estimate the reverberation level in an area under the prevailing conditions. In this country some studies relating to the Arabian Sea have been made by the scientists of the Naval Physical and Oceanographic Laboratory. The research vessels RV *Gaveshani* and RV *Sagar Kanya* have been utilised for collecting the field data and will play even a greater role in future extensive studies.

Sea reverberation is a process relating to the time variation of the scattered sound field, as observed at the point of reception of the acoustic signal which has been transmitted earlier. When the sound waves from a radiating transducer of a sonar system propagate in the ocean, they are scattered by:

a) the irregular bounding surface at the top (wavy sea surface),

b) the irregular bounding surface at the ocean bed and

c) the inhomogeneties, biological and physical, e.g. marine life, air bubbles, suspended particles, temperature inhomogeneties present in the sea.

The reverberations arising from (a), (b) and (c) above are respectively referred to as surface, bottom and volume reverberation. A schematic showing the geometry of the bottom reverberation is shown in fig. 1.

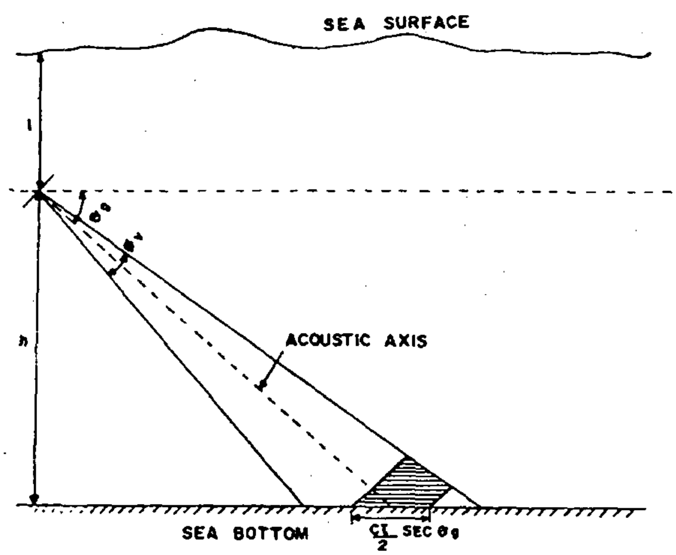

Fig. 1. Geometry of the reverberation experiment.

The back-scattered signal intensity is determined by the radiated power, the signal waveform, the directivity index of the transducer, the attenuation in the water and by the scattering strength of the scatterer. The scattered intensity increases with the transmitted power, the duration for which the reverberation lasts is influenced by the transmission waveform, a CW pulse generating reverberation of a longer duration than a frequency modulated pulse (figs. 2 and 3). The intensity of the reverberation returns is less for a directional transducer.

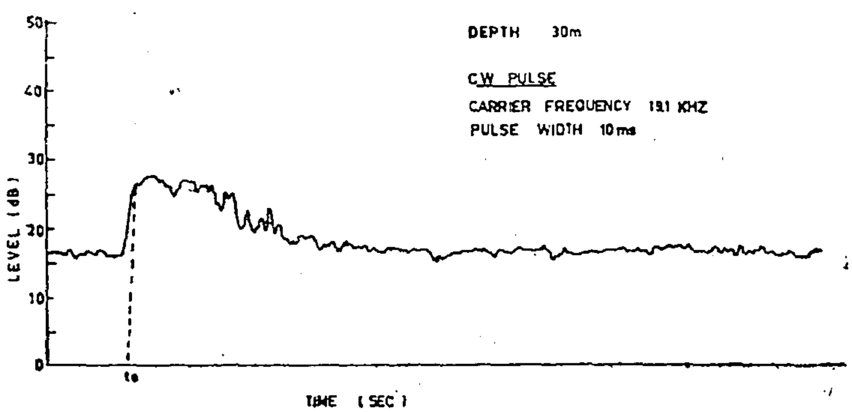

Fig. 2. Time base plot of reverberation

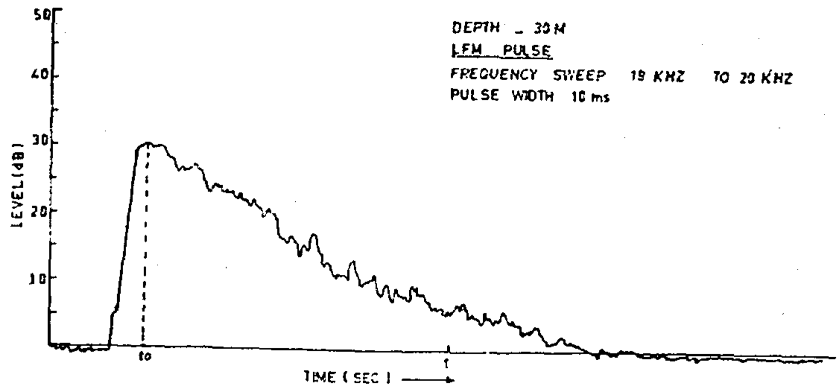

Fig. 3. Time base plot of reverberation.

The scattering strength of a scattering medium is defined as the ratio in decibels, of the intensity of sound, scattered by unit area or unit volume, referred to a distance of 1 yard to the incident plane wave intensity and is given by the equation:

$$S_{V \text{ or } S} = 10 \log \frac{I \text{ scatt}}{I \text{ inc}} \qquad (1)$$

The scattering cross-section of the scatterer is defined as the ratio of the scattered power referred to 1 yd to the incident intensity on unit volume or area. The scattering strength mv or ms is given by:

$$S_v = 10 \log \frac{mv}{4}$$

$$S_s = 10 \log \frac{ms}{2}$$

Where mv and ms are the back scattering cross-sections of unit volume or area and S_V and S_s are the volume and surface scattering strength.

Voluminous literature is available on the bottom reverberation characteristics measured experimentally in the Pacific and Atlantic Oceans (Tolstoy and Clay, 1968; Clay and Leong, 1975; Ol Shevhii, 1967; Eckart, 1953; Mc Kenzie, 1960; Mc Kiney and Anderson, 1964). Reverberation models have also been developed by a number of authors adopting either the physical approach or discrete scatterer approach (Middleton, 1967a & b, 1977).

Studies in the Indian shelf regions are meagre and have been initiated only recently. In characterising the reverberation features of the Indian Coastal regions, two methods have been adopted:

a) the physical features of the bottom or the surface (e.g. roughness) and their acoustic characteristics (e.g. reflection or scattering coefficient) are experimentally determined and a theoretical model of the scattered field is built up.

b) experimental determination of the scattering strength of the bottom or surface and its correlation with the contributing scatterer parameters thus leading to a heuristic model.

In the theoretical approach for a reverberation model the illuminated volume of the ocean, its surface and bottom is divided into cells, and for each cell, the sonar equation is solved in order to determine the back-scattered signal level received by the sonar, taking into account the scattering strength of the surface/bottom/scatterers, attenuation transmission directivity (Hodgkiss, 1984). The model can be further extended to include ship motion, transmission signal waveform and the ocean sound velocity profile. Such a model is useful in predicting the reverberation field likely to be seen by a sonar. The accuracy of the model depends on the accuracy of data relating to the parameters (e.g. the surface roughness acoustic properties of the bottom layer etc.),

Bottom scattering/reflection loss model for the Indian West Coast shelf water was given by Srinivasan, Murthy and Murthy (1982). From an analysis of the echograms of the sea bed, the roughness distribution of the ocean bottom is known. The sediment distribution in the area and its features like phimedian and porosity (fig. 4) investigated by Murthy (1978) enables one to estimate the acoustic characteristics such as acoustic impedance, sound penetration depth and attenuation. The scattered pressure field as well as the bottom losses for the shelf region off the West Coast of India are then calculated. Their studies led to the following conclusion:

a) Between 30 and 50 fathom line the bottom is relatively smooth with silty clay; between 50 and 70 fathom line sands are predominant while coarser sand with relief in the range 1-2m is the main feature in the outer shelf (fig. 4).

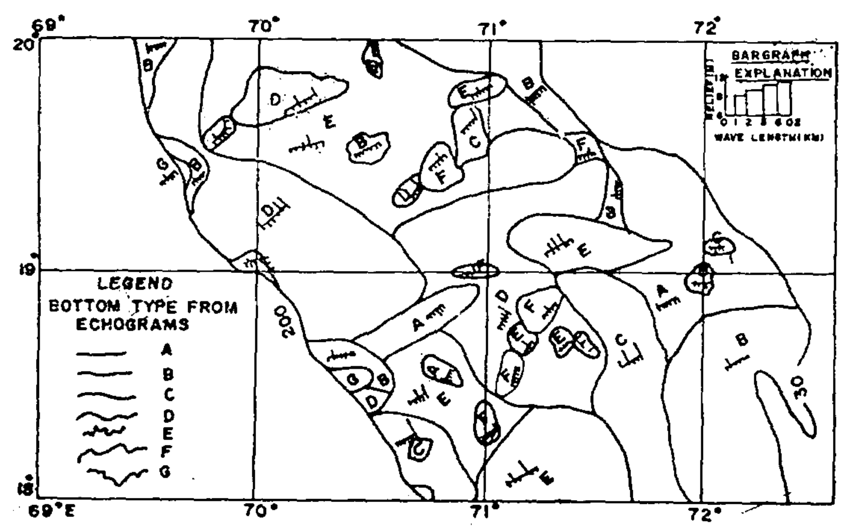

Fig. 4. Spectral estimates of bottom topography.

b) Consequently scattering loss is more predominant than the reflection loss in the outer shelf region while reflection is more predominant in the 30-50 fathom line.

Typical values of the scattering loss for 7.5 KHz acoustic beam of 3 beam width in the area are given in (fig. 5).

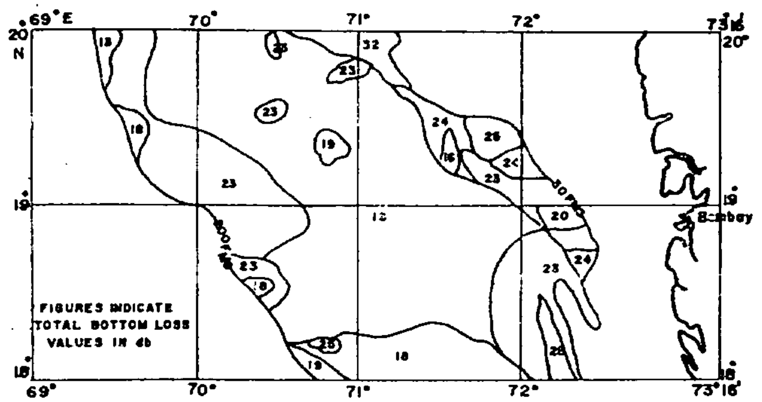

Fig. 5. Bottom loss model (estimates based on 3° beam width 7.5 KHz signal frequency at vertical incidence).

For establishing an empirical model, Madhavan and Vijayakumar (1981) carried out field measurements on board RV *Gaveshani* in the continental shelf region of the West Coast at depths from 35m to 146m. They used a transmitting array of 95 KHz, as well as explosive sources for generating sound beam. In the former case, different signal wave forms were used. A schematic of the experimental set-up is shown in fig. 6.

A transducer array mounted on a rigid framework was suspended from a stationary ship with all its machinery stopped. The return signals (scattered from the sea bottom) were received by the array, amplified, filtered and recorded. From the geometry of the area and the sound ray plots, the time for bottom return can be estimated and the reverberation signals identified in the record. From an analysis of the signal amplitude, the back scattering strength is calculated using Urick's formula:

$$RL = SL - 40 \log r + S_B + 10 \log \frac{CT}{2} \operatorname{Sec} \phi \, (r\,\theta)$$

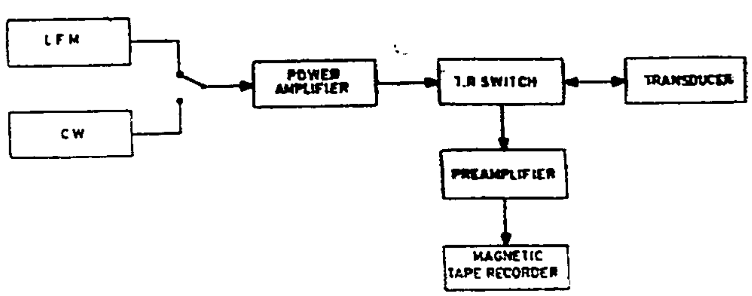

Fig. 6. Block diagram of the system for recording reverberation.

where RL — Reverberation level in decibels

SL — Source level in decibels

r — distance

S_B — Bottom scattering strength

C — Velocity of sound

T — Pulse length

ϕ — Transmission beam width

θ — Angle of tilt

Madhavan's (1983) values for the back scattering strength between Goa and Bombay in the outer shelf region vary around-28 dB and between Cochin and Goa in the coastal region vary around — 33 dB.

By a series of field measurements similar to the ones just described, it is possible to construct an empirical model, correlating it with the bottom features, as well as with the signal characteristics.

Conclusion :

The paper presents a summary of the work done on estimating the reverberation levels in the Indian Coastal regions. Considering the importance of this information for sonar designers and users and the vast shelf areas of interest, more field work is called for before a realistic model is constructed.

The paper is presented as a tribute to the sustained interest in this work and the ready response to NPOL requests for assistance in the work shown by Dr. V.V.R. Varadachari, Director, NIO.

REFERENCES

Clay C.S. and Wing K. Leong, 1974. Physics of Sound in Marine Sediments, Plenum Press, NY, 373 pp.

Eckart C.J., 1953 Scattering of sound from the sea surface, *Journal of Acoustical Society of America*, **25**: 566.

Hodgkiss W.J., 1984, An oceanic reverberation model, *IEEE Journal of Ocean Engineering* OE **9**: 63–72.

Madhavan C., and O. Vijayakumar, 1981, Measurements of back scattering of sound from the ocean bottom, *Jonrnal of Acoustical Society of India*. **9**: (1) 1–5.

Madhavan C. 1983. *Ph. D. Dissertation*, Indian Institute of Science, Bangalore.

Mc Kenzie K.V., 1960, Bottom reverberation for 530 and 1030 Hz sound in deep waters. *Journal of Acoustical Society of America*, **32**: 221.

Mc Kiney C.M., and C.D. Anderson, 1964, Measurement of back scattering of sound from the ocean bottom. *Journal of Acoustical* Society of America, **36**: 158–163.

Middleton D., 1967a, A statistical theory of reverberation and similar first order scattered fields. Part I wave forms and the general processes. *IEEE Trans - Information Theory,* **13**: 372–392.

Middleton D., 1967b. A statistical theory of reverberation and similar first order scattered fields. Part II Moments, Spectra and spectral distribution, *IEEE Trans - Information Theory,* **13**: 393–414.

Middleton D., 1977, A statistical theory of reverberation and similar first order scattered fields Part III wave form and fields, *IEEE Trans - Information Theory* **18**: 35–67.

Murthy, G.R.K. 1978. NPOL (unpublished). Report no. 2/1978.

Ol Shevshii V.V., 1967 Characteristics of sea Reverberation, *Consultant Bureau,* NY.

Srinivasan D., K.R.S.K. Murthy and S.R.K. Murthy, 1982. Underwater sound scattering model of the topographic features of the sea floor, *Defence Science Journal*, **32**: 1–8.

Tolstoy I. and C.S. Clay, 1960. Ocean Acoustics, Mc Graw Hill Book Co., NY.