Sea-bed motion as a source of the ambient noise background of the sea

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Some 12 years ago, G.M. Wenz hypothesized, on the basis of scanty data, that the seismic unrest of ocean floor was possible cause of the low-frequency noise background of the deep sea. In the present note this idea is reexamined quantitatively in the light of subsequent measurements with seismometers on the sea bed. It is found that the noise levels likely to result from sea-bed motion of the sea are indeed comparable with those of shipping, and therefore, must be included in models to explain and predict the level of the ambient noise background of the sea.

Subject Classification: 30.70.

INTRODUCTION

In a classic paper[1] published in 1962, Gordon Wenz suggested that the noise background at low frequencies in the sea may be due to seismic sources. That is to say, the motion of the sea bed due to seismic unrest causes sound in the ocean above it, and so contributes to the ambient acoustic background at low frequencies where seismic unrest is known to be relatively large. Although Wenz speculated that this source of noise could be important in the frequency range 1–100 Hz, little evidence could be produced at the time to support the hypothesis, since no ocean-bottom seismic measurements had been made.

Since then, a number of observations of deep sea-bed motion, mostly motivated by the VELA UNIFORM program aimed at nuclear blast detection, have been made and published. These measurements are neither numerous or definitive, and do not extend into the frequency region above 10 Hz. The purpose of this note is to summarize these recent measurements, such as they are, and thereby to examine afresh the hypothesis that bottom motion is an important contributor to sound in the sea.

I. THE DATA

Only four papers giving quantitative spectral data on sea bottom motion have been uncovered in a brief literature search. While reported seismic data was obtained in a variety of ocean areas, the published results are based on only short data samples, and are reported in a variety of units. In Table I,[2–6] the first four columns summarize the reported levels of the amplitude or velocity of the ambient background of sea-bed motion, as read at a number of frequencies from spectral curves in the referenced papers. Column 5 of Table I gives values of mean-square bottom velocity in decibel units, or $10 \log \overline{v^2}$, where v is the bottom seismic velocity in (cm/sec)/Hz. These velocity levels correspond to the

TABLE I. Reported and computed levels.

1 Reference	2 Location	3 Freq. (Hz)	4 Reported amplitude or velocity in stated bandwidth	5 velocity[a]	6 Computed sound level (dB re 1 μPa)
2	65 km south of Bermuda	1	3×10^{-4} μ^2/Hz	−99	+115
		3	10^{-6} μ^2/Hz	−114	+90
3	Off Catalina Island	1	10^{-3} $(\mu/\text{sec})^2$/Hz	−110	+94
		2	10^{-4} $(\mu/\text{sec})^2$/Hz	−120	+84
4	Off Hawaii and San Diego	1	1 $(\mu/\text{sec})^2$/Hz	−80	+124
		5	10^{-2}	−100	+104
		8	10^{-2}	−100	+104
5 (a)	Southwest of Bermuda	1	10^{-1} μ in 1 octave band	−84	+124
		10	5×10^{-4} μ in 1 octave band	−130	+74
5 (b)	Gulf of Mexico	1	5×10^{-2} μ in 1 octave band	−90	+114
		3	10^{-3} μ in 1 octave band	−124	+80
6 avg	Average of numerous land stations	1	10^{-2} μ in 1/3 octave band	−92	+112
		10	5×10^{-4}	−118	+86
		100	5×10^{-5}	−138	+66
min.	Average quiet land stations	1	10^{-3} μ in 1/3 octave band	−112	+92
		10	5×10^{-5}	−138	+60
		100	5×10^{-6}	−158	+46

[a]dB re (1 cm/sec)^2/Hz.

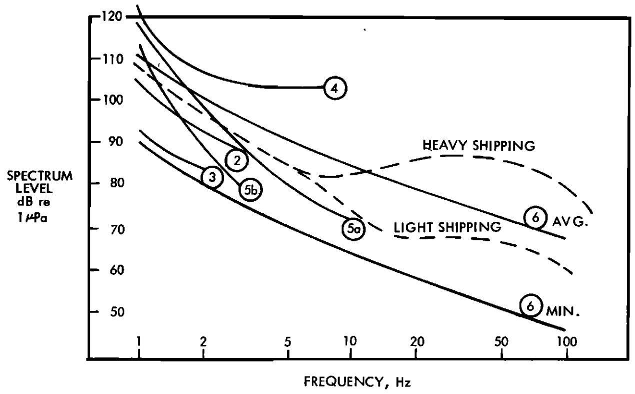

FIG. 1. Inferred seismic noise spectra drawn from values in Table I. Circled numbers refer to numbered references. Dashed curves are average measured spectra in deep water.

published values given in Column 4. Column 6 gives the corresponding acoustic spectrum levels, based on the plane-wave relationship

$$\overline{p^2} = (\rho c)^2 \overline{v^2}, \text{ or } 10 \log I = 10 \log \overline{p^2}$$
$$= 104 + 10 \log \overline{v^2} \text{ dB } re \text{ 1 dyn/cm}^2.$$

II. CONVERSION OF SEA-BED MOTION TO SOUND

This conversion of bottom velocity to acoustic pressure, as made in this simple way, assumes that the sea bottom is an infinite surface radiating plane waves into an infinite medium. Two effects make this assumption questionable. One effect is caused by the ocean surface, which reflects the radiation back into the sea and so increases the sound level; thus, if sound is initially radiated with unit intensity, the average total intensity, after successive reflections from a sea surface having unit reflection coefficient and from a sea bottom having an intensity reflection coefficient equal to R, will be $1 + R + R^2 + \cdots = 1/(1 - R)$. If the bottom loss, $10 \log R$, is 1 dB so as to make $R = 0.8$, the intensity would be increased by the ratio $1/(1 - 0.8) = 5$, assuming power (random-phase, broad-band) addition of the successive reflections.

A compensating effect is produced by the fact that the bottom does not radiate uniformly as a plane-wave radiator, but rather, some parts of it in the vicinity of the receiver will be out of phase with others, and so will reduce the acoustic level in the water above. This will occur if the bottom motion is due to waves traveling horizontally, such as Rayleigh waves. This problem, namely, the radiation of Rayleigh waves into a fluid, has been worked out theoretically by Brekhovskikh.[7] In any case, we may hope that the combined effect of these two complexities is negligible and that the sound level computed by assuming plane-wave radiation is roughly correct, at least as to order of magnitude.

Figure 1 is a plot of the spectrum levels listed in the last column of Table I and connected by solid lines. The dashed lines give the approximate sound-spectrum levels measured in deep water under conditions of heavy and light shipping. The curves extending to 100 Hz, taken from Ref. 5, are based on the average and minimum seismic motion measured at numerous stations on land.

III. CONCLUSIONS

We observe from Figure 1 that:

(1) The seismic motion of the deep sea bed is generally and roughly the same as that on land. This conclusion has been repeatedly noted in reports of sea-bed measurements.

(2) The acoustic levels resulting from this motion are comparable with those found in the sea, especially under conditions of light shipping in seismically active areas.

(3) Seismic motion as a contributor to sound in the sea, therefore, cannot be ignored in models intended to predict the level and directivity of ambient sea noise, and must be included in these models at low frequencies.

[1] G. M. Wenz, "Acoustic Ambient Noise in the Ocean," J. Acoust. Soc. Am. **34**, 1936 (1962).
[2] G. V. Latham and G. H. Sutton, "Seismic Measurements on the Ocean Floor," J. Geophys. Res. **71**, 2545 (1966).
[3] W. A. Schneider and M. M. Backus, "Ocean Bottom Seismic Measurements off the California Coast," J. Geophys. Res. **69**, 1135 (1964).
[4] H. Bradner and J. G. Dobbs, "Comparative Seismic Noise on the Ocean Bottom and on Land," J. Geophys. Res. **69**, 4339 (1964).
[5] D. D. Prentiss and J. I. Ewing, "Seismic Motion of the Deep Ocean Floor," Bull. Seismol. Soc. Am. **53**, 765 (1963).
[6] J. N. Brune and J. Oliver, "Seismic Noise of the Earth's Surface," Bull. Seismol. Soc. Am. **49**, 349 (1959).
[7] L. N. Brekhovskikh, *Waves in Layered Media* (Academic, New York, 1960), pp. 38–44.