NOISE SOURCES IN THE OCEAN

(Part II)

by

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ABSTRACT

Following a brief historical survey of the development of our knowledge of the origins and characteristics of ambient noise in the ocean, the principal known sources of noise are described. These are: environmental origin, biological origin and man-made. The combination of these sources leads to the modified Knudsen curves which are variable both in time and space. Methods of measurement of noise are reviewed. A state-of-the-art tabulation of the geographic, frequency and time dependence of various sources of noise is presented as a starting point for discussion. The text is in two parts, of which this is the second.

Before continuing the brief discussion of noise sources in the ocean it seems appropriate to illustrate by an example the sort of difficulty that arises in experimental studies.

Figure 1 shows diagrammatically a simple model of the way in which sound is received by a directional hydrophone from noise sources distributed uniformly over the sea surface. Comparing the two idealized beam shapes (corresponding to different angles of elevation of the hydrophone), it is obvious that the area scanned by the hydrophone is proportional to the square of the range. If we assume a spherical spreading propagation law, and isotropic noise sources, the increase in effective radiating area just compensates for the spherical spreading loss. Even if we assume anisotropic sources (e.g. dipoles or quadrupoles), the effect on received level is slight; as is well known, in all these situations the integration for an omni-directional hydrophone gives an integral which diverges to infinity.

It follows (Fig. 2), that the measured directional properties of the sea surface noise are determined principally by the residual propagation loss due to absorption. In other words, the measurements are very insensitive to the directional properties of the noise sources, and the interpretation of the results usually tell us more about the attenuation coefficient than about the mechanism of surface noise.

A similar effect occurs if we change the depth of the hydrophone; the decrease of noise level with depth is dominated by absorption.

Since attenuation coefficients are often not known accurately enough it would be a natural conclusion that the way to avoid this problem, if we wish to measure the directivity pattern of the noise sources, would be to keep the ranges very short — i.e. to place the measuring hydrophone near the sea surface. But this has its penalties. Stabilising the hydrophone presents great difficulties, particularly if we are trying to measure noise at high states. In addition, the effect of side lobes in the hydrophone beam pattern is a serious problem.

It is not surprising therefore that there have been relatively few reliable measurements of the vertical directivity of noise sources; the measurement calls for great skill in experimental design. It is even less surprising that some early measurements, although carefully carried out, failed to give acceptable results; misinterpretation of the data was not infrequent.

Returning now to the origins of noise at the sea surface there are a few mechanisms additional to those listed by Dr Wille (Fig. 3).

The first of these is rain. Droplets falling in the sea-surface can produce a very high noise level — increases of up to 30 dB during a rain squall have been observed experimentally.

The mechanism is moderately well understood, but the phenomenon, being intermittent, and depending critically on the rate of rainfall, droplet size, etc., is for practical purposes unpredictable in quantitative terms.

A second possible mechanism, almost uninvestigated, is the presence and collapse of near-surface aeration. Such aeration is known to exist, although data on its magnitude are sparse, but how important it is is unknown. A further complication is that in the presence of aeration the properties of the medium may be affected, and this itself could modify the noise levels produced by any surface mechanism, e.g. by altering the acoustic impedance into which noise sources are radiating.

The last surface mechanism is that due to ice cover. This has been quite extensively studied in the Arctic, by workers from both the U.S.A. and Canada. What happens depends very strongly on the nature of the ice cover. Under a loose ice pack noise levels may be higher by perhaps 10 dB than in the open ocean. On the other hand under a continuous stable ice cover noise levels may be very low — in some instances the lowest ever recorded.

The character of the noise is very variable, ranging from a familiar continuous spectrum to a series of cracks and spikes.

Although many measurements have been made, the prospects of prediction for modelling are not bright. Milne, one of the most active workers in this field, has stated bluntly that at present prediction is just not possible.

Additionally, I should mention that an intermittent source of noise is occasioned by icebergs. As they drift, melt and collapse they produce a local intense source of (usually) non-Gaussian noise.

The last natural source of noise is of molecular origin. This is the thermal noise of the sea itself (Fig. 4). This source has the unusual property that it increases in level with increasing frequency (at 6 dB per octave). It is therefore significant only at high frequencies (above 100 kHz, viz.) and even then only when other sources are of very low intensity. As an example thermal noise has been observed experimentally under stable ice in the Arctic.

Generally, however, this noise is swamped by the other sources. It is particularly ironic, therefore, that this is one of the few mechanisms that can be theoretically predicted with quantitative accuracy.

This concludes the brief list of noise sources of natural origin, and I now turn to another group of sources arising from human activity (Fig. 5).

The first mechanism, mentioned earlier by Dr Wille, is that of distant shipping, which tends to dominate the low-frequency end of the spectrum (say 10 to 200 Hz). In principle it should not be too difficult to calculate the levels to be expected, given adequate data on shipping density. One point should be borne in mind. At these frequencies absorption losses are low and, by the arguments used earlier, contributions from far-distant ships will be important (as was shown by Dr Wille in his Baltic example).

The second source is of varied nature. It is that arising on land from industrial activity (traffic, mining, heavy engineering, etc.). Clearly this will be of importance in coastal waters, and here it can be significant. It is almost impossible to be quantitative, however. Not only the magnitude of the sources themselves, but the nature of the coupling of acoustic energy from land to sea, and the often anomalous propagation conditions near the coast, all combine to present a virtually unpredictable situation.

Traffic has been mentioned. A second traffic source might be expected to be the passage of aircraft. Little work has been done on this. At first sight the poor acoustic coupling between air and sea suggests that there may not be a serious effect, but it should be remembered that across the sea-surface pressure is transmitted unchanged, even though energy is very poorly coupled.

Other speculative sources of noise might be expected to increase in importance with the growing pace of undersea exploitation of natural resources. Explosion and the operation of drilling on prospecting platforms may be a source of 'industrial' noise. Since the coupling to the sea is, presumably, much more efficient than that for land-based sources, there is at least a presumption that this mechanism may, at least in some areas, become significant. This is, however, an unexplored field to date.

Finally I turn to the last group of noise sources — biological noise (Fig. 6). As Dr Wille has mentioned this is by far the most intensely studied and best documented of all mechanisms — as Dr Wille has pointed out, disproportionally so.

There is a rough classification of this type of noise into two classes: the quasi-continuous and the intermittent.

In the first class the classic example is that of the snapping shrimp, a bed of which can produce a persistent crackling noise which acts as a significant — and non-Gaussian — background. This type of noise is strongly localised, usually to coastal areas.

In the second class the grunts, squeals, groans, etc, of marine mammals (such as whales and dolphins) are well-known to any sonar operator. They can be distracting, but have, usually, the advantage of being strongly characteristic, so that they can readily be recognised and discarded.

On the whole, my feeling is that, usually, these acoustic effects are of greater value and interest to the biologist than to the acoustician. For example, the '20 cycle monster' (a long pure tone note heard on occasion in the Pacific) is of no great significance for sonars, but has presented the biologists with a fascinating problem (it is now plausibly believed, though not conclusively demonstrated, that it originates from a member of the whale family).

This concludes this extremely brief survey of noise sources. I must conclude by repeating Dr Wille's remarks: our knowledge of ambient noise is incomplete and not always properly documented; its study is difficult, expensive, and time-consuming; and if it is felt that better knowledge is required for sonar modelling purposes, it is difficult to see how anything less than full international collaboration could be adequate.

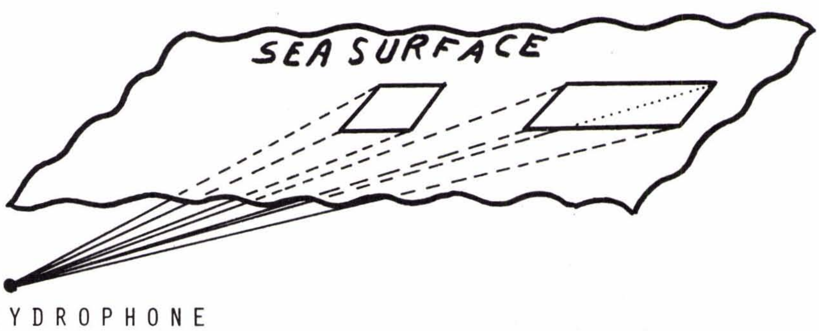

FIG. 1 EFFECT OF RANGE ON NOISE LEVEL FOR A DISTRIBUTED SOURCE

- DEPTH AND RANGE EFFECTS DOMINATED BY ABSORPTION
- DIFFICULTY IN MEASUREMENT OF DISENTANGLING CONTRIBUTIONS BY
  - SOURCE CHARACTERISTICS (E.G. DIRECTIONALITY)
  - DIRECTIVITY PATTERN OF HYDROPHONE
  - PROPAGATION

FIG. 2 DISTRIBUTED SOURCE

- RAIN
- BUBBLES?
- ICE

FIG. 3 SEA SURFACE

- INCREASES WITH FREQUENCY (6 dB PER OCTAVE)
- IMPORTANT AT HIGH FREQUENCIES (>100 kHz) UNDER STABLE ICE)

FIG. 4 THERMAL NOISE

- SHIPPING
- INDUSTRIAL, ETC.
- AIRCRAFT
- OTHER DISTANT SOURCES (E.G. EXPLOSIONS)
- DRILLING/PROSPECTING PLATFORMS?

FIG. 5 MAN-MADE NOISE

- FISH
- MARINE MAMMALS
- CRUSTACEANS
- 20-CYCLE MONSTER?

FIG. 6 BIOLOGICAL NOISE