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NON-TIDAL INFLUENCES IN SHALLOW WATER SOUND PROPAGATION; THE EFFECTS DUE TO FISH

BY

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Introduction

This is the companion to paper [1] which covered the tidal influences and more specifically the normal-mode nature of propagation. Here some of the non-tidal influences are discussed especially those associated with fish.

Diurnal effects due to fish

Large changes in received signal level may often be noticed at sunrise and sunset, and were first discovered in 1963 [2]. The patterns were attributed to fish largely because of the timing relative to light intensity and the knowledge that fish shoals break up when it gets dark and reform when it becomes light. The scattering and absorption of sound by the fish depends on their degree of aggregation; this is particularly important for pelagic fish having swim bladders. At night the fish swimming as individuals can produce a high overall attenuation. In the daytime when they are packed into shoals there is acoustic interference between the scatterers, and the attenuation they produce is less.

A systematic series of multifrequency amplitude fluctuation experiments were carried out in the Bristol Channel at regular intervals between May 1967 and September 1968 [3]. A sequence of pulses of 4 s duration at frequencies between 700 Hz and 3.5 KHz was transmitted every 100 s, and received at ranges of 23 and 137 km.

Seven different diurnal patterns of attenuation against time have been distinguished [4] and a schematic representation of these patterns is shown in Figure 1. It is convenient to show patterns as centred about local midnight rather than midday. The first three patterns are the simplest and most common. Pattern 1 is an abrupt drop in signal level after sunset, often between 15 and 25 dB, followed before sunrise by a similar abrupt rise in level. Pattern 2 is a dip in signal level of between 10 and 20 dB, after sunset and before sunrise. Pattern 3 is a bowl-shaped gradual change in signal level of between 5 and 15 dB giving a reduced signal level at night.

The character and magnitude of the patterns is very variable and is due in part to changes in number, type and aggregation behaviour of pelagic fish. There may also be a contribution from bottom-living fish which may swim upwards in the water column around twilight. In addition, pelagic fish will often assume a shallower depth near dusk. Acoustically the depth of the fish is important for three distinct reasons. First, the bladder resonance frequency is a function of depth. Secondly, there is the Lloyds mirror interference effect occurring near both the surface and the bottom. The acoustic pressure is reduced, the fish are partly decoupled from the acoustic medium and the attenuation is reduced. Thirdly, the sound velocity structure may channel the sound, usually in the lower half of the water column. This is important for the 137 km path, particularly in the summer months, and deep fish can then have much more effect than shallow fish.

The amplitude of the change in signal level for each pattern has been plotted against the time of year in Figure 2 for the short range 23 km path. The pattern may involve an increase or decrease in signal level at night. The main effects over this path occur between July and September, the higher frequency transmissions being affected about a month earlier than the lower frequencies. The maximum observed attenuation of at least 45 dB occurred at 700 Hz, which is the lower limit of the measurements. But it does seem as if the effect peaks at this frequency, with a Q-factor of about 2. A bladder resonance of 700 Hz corresponds, with a few reasonable assumptions, to a fish length of 24 cm, almost certainly the Cornish Pilchard. There is a second frequency peak at about 3.2 kHz, corresponding to a 5.3 cm length, with no obvious fish candidate responsible.

From the measured attenuation and frequency it was possible to estimate the mean numbers of fish in the 24 cm category as at least 0.12 per m^2 of sea surface with mass about 12 gm per m^2, or 110 lb per acre.

For the 137 km path the attenuation patterns are not limited to the summer months and there are no marked frequency dependence effects as for the 23 km path.

Seasonal variation in propagation

It is possible that the diurnal variation of the fish effect is not a full-depth modulation, i.e. there may also be some fish attenuation remaining. This helps to explain the observed characteristics of shallow-water propagation, and is partly supported by the seasonal dependence of the daytime transmission. The increased losses in the summer are apparently due to a mixture of thermal and fish mechanisms [3].

Wind attenuation

High winds, or rough seas, attenuate the signal level, affecting the higher frequencies first [5]. It has been observed at times that the lower frequency transmissions are attenuated first in the daytime when the diurnal fish patterns are present. This is presumably because the fish shoals have been dispersed by the rough seas and this has caused the attenuation.

Fast fluctuations

Another fluctuation effect occurs in the summer daytime over the short range path [2, 6]. During the night the envelope of the pulses is smooth, but during the day the amplitude variation is considerable and the envelope is rough, with a typical period of some minutes. The timing of the effect is closely allied to the attenuation patterns, suggesting that the cause is again fish. This effect occurs over the whole frequency range, and is most pronounced in August.

Other non-tidal influences

Another possible cause of fluctuation, not connected with fish, is a diurnal thermal effect. With our shallow-water geometry this is expected to be small however.

This paper has dealt only with amplitude fluctuations, but there are also phase effects. The seasonal change in mean temperature of the water affects the phase delay, which is least in the summer due to the higher temperature and sound velocity.

Conclusions

The breaking up of the shoals of bladder fish can cause very large night-time falls in signal level. Such fish attenuation may also affect the mean daytime propagation curve, its seasonal variation and its dependence on wind. In general (see also ref. 1) attention is drawn to the large variety of causes of shallow-water fluctuation, and the consequent difficulty in understanding and predicting transmission loss.

References

1. WESTON, D.E., 1969, Preprint for British Acoustical Society Symposium on Underwater Acoustic Propagation. Tidal influences in shallow-water sound propagation; the normal-mode effects.

2. WESTON, D.E., HORRIGAN, A.A., THOMAS, S.J.L. and REVIE, J. Phil. Trans. Roy. Soc. In press. Studies of sound transmission fluctuations in shallow coastal waters.

3. STEVENS, K.J., REVIE, J. and PENGELLY, M. Multiple frequency studies of sound transmission fluctuations in shallow water. In preparation.

4. CHING, P.A. and WESTON, D.E. Shallow water acoustic attenuation due to fish. In preparation.

5. CHING, P.A. and WESTON, D.E. Wind effects on shallow water sound propagation. In preparation.

6. CHING, P.A. and WESTON, D.E. A shallow water acoustic transmission fluctuation occurring in the summer daytime. In preparation.

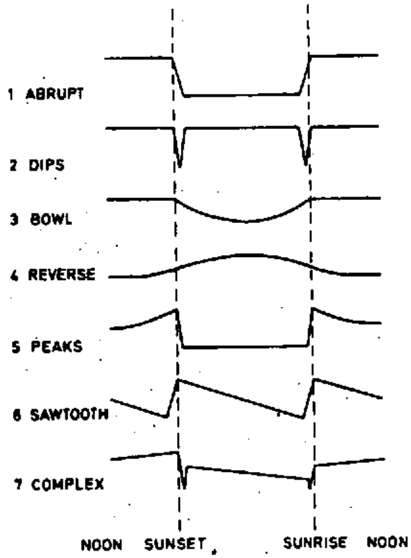

FIG. 1 SCHEMATIC REPRESENTATION OF ATTENUATION PATTERNS DUE TO FISH

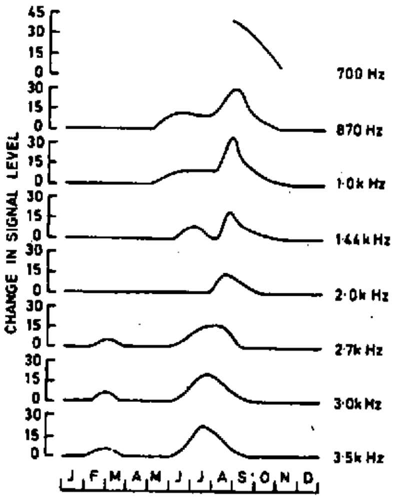

FIG. 2 SEASONAL DEPENDENCE OF DIURNAL LEVEL CHANGES OVER 23km PATH