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WIND EFFECTS IN SHALLOW WATER ACOUSTIC TRANSMISSION

Miss P. A. Ching (Admiralty Research Laboratory)

Introduction

It is well known that underwater sound is reflected and scattered by the sea surface but little has been published for shallow water transmission. The effect of wind on transmissions in shallow water has been illustrated in [1], as the wind rises the transmission loss increases and the resulting attenuation of signal level is quite dramatic.

A series of multifrequency experiments was carried out in the Bristol Channel between 1967 and 1969 to study fluctuation mechanisms in shallow water transmission, especially the frequency dependence of fish attenuation effects. Strong winds frequently occurred during these experiments thus giving an opportunity to study the effect of the wind on the signal level. The experiments were not designed for this purpose and therefore some of the desirable parameters were not measured. For instance the wave height was not recorded but general information on wind speed and surface conditions in the area is available. A record of wind speed along the propagation paths would have been an advantage but this would have been impracticable due to the unpredictability of the times of occurrence of strong winds and the extended time scale of the experiments. Measurements of wind speed were made at shore stations some distance away.

Effect of wind speed on received level

A sequence of seven pulses at frequencies between 870 Hz and 3.5kHz was transmitted every 100 sec and received at ranges of 23 and 137 km. Measurements lasting 2 or 3 days were made about once a month between May 1967 and May 1968 after which time the experiments were repeated sometimes for longer periods and occasionally extending the frequency range from 300 Hz to 4.5 kHz. The source level was not the same at all frequencies.

As the wind speed increases three changes take place; the ambient noise level increases, the signal level is attenuated with an attenuation that increases with frequency, and the pulse to pulse fluctuation increases. An example of the envelope of the pulses received over the 23 km path is shown in fig 1 together with the wind speed at the recording site.

The dependence of signal attenuation on frequency and increasing wind speed is shown in fig 2. Most of the records showed a similar relationship with the attenuation increasing with both wind speed and frequency. The degree of attenuation also depends on the direction of the wind. For example the attenuation at 2 kHz over the 23 km path, for wind speed of 20 kt, varies by nearly 30 dB depending on its direction. A few records showed slightly different characteristics, fig 3, with an additional peak attenuation at about 14 kts.

When the wind speed decreased similar curves were obtained but it often took many hours for complete recovery of signal level.

Over the longer, 137 km, path the effect of wind on the signal level is obviously more complicated because of the variability in conditions along the path. Although the signal level over the long path is lower due to increased transmission loss the additional attenuation due to wind is not apparently greater than for the short path.

Squalls

Squalls, or sudden and strong gusts of wind often accompanied by rain, have a pronounced effect on the signal level which can drop suddenly by about 20 dB and quickly recover. The attenuation during the squall appears to be higher than that expected for a steady wind at a similar speed but it must be remembered that the wind speed is recorded on land and may not be as high as the gusts of wind over the propagation path.

Fish

Large changes in received level may often occur at sunrise and sunset. The changes are attributed to fish largely because of the timing relative to light intensity. At night fish with swim bladders, swimming as individuals scatter and absorb the sound and produce a high overall attenuation. In the daytime when they are packed into shoals there is acoustic interference between the scatterers and the attenuation is less. These attenuation patterns are most pronounced in the summer months at frequencies between 700 Hz and 1 kHz.

On a few of the records increasing wind attenuated the low frequencies before the higher frequencies. On each occasion when this happened the preceding record has shown the attenuation patterns due to fish at the low frequencies and it is probable that the increasing wind and roughening seas cause the fish shoals to disperse, thus causing additional attenuation at the lower frequencies.

Attenuation, frequency and wave height

Let us now consider the causes of the basic attenuation effects on figs 1, 2 and 3.

The surface roughness must play an important part in the attenuation of the signal level. Two main conditions of wind and wave height occur along the short propagation path. On-shore winds have crossed over a sufficient area of sea to develop the waves although not necessarily to the same height as would have been produced in open sea. The wave height increases with wind speed and the attenuation varies experimentally as about $(fh)^{3/2}$, where f is frequency and h is mean wave height. This is the relationship postulated by Marsh, Schulkin and Kneale [3] for surface duct propagation. This applies only for fh products less than 10, above which the attenuation increases rapidly. Off-shore winds have travelled over a very limited area of sea and there is little increase in wave height with wind speed up to 30 kt. The attenuation is usually lower than for on-shore winds and the fh product relationship does not seem to hold.

Bubbles

Bubbles entrained in the medium may also account for some attenuation. Like fish, bubbles will absorb and scatter the sound especially near resonance. Bubble radius for resonance at the frequencies recorded would be between 0.4 and 0.07 cm but these would be much larger than bubbles reported to be generated by wind, most of which are between 0.01 and 0.02 cm [2]. Very few, if any, bubbles near resonance would be present, but there would be large numbers of small bubbles and the effect of these has not yet been investigated.

Breaking waves always cause a number of bubbles, but when the wind is opposing the direction of swell the tops of the waves are blown off causing considerable spray which in turn would increase the bubble population. When the wind is blowing in this direction the measured attenuation is very high. An increase in the number of bubbles can also be caused by rain, hail or snow. Signal attenuation has been recorded during hail storms and the additional loss in signal level during squalls may be due to bubbles. Perhaps the peak attenuation at 14 kt (fig 3) can also be explained by the presence of bubbles, as at this wind speed the presence of 'white caps' is noticeable but it must be remembered that the attenuation at this wind speed is not usually high.

Conclusions

Winds can cause considerable signal attenuation especially at frequencies above 1 kHz. In shallow coastal water the direction of the wind is important. Signal attenuation is caused by the roughened sea surface and may be increased by bubbles entrained in the sea from breaking waves and precipitation. Fish sometimes cause high attenuation at the lower frequencies.

References

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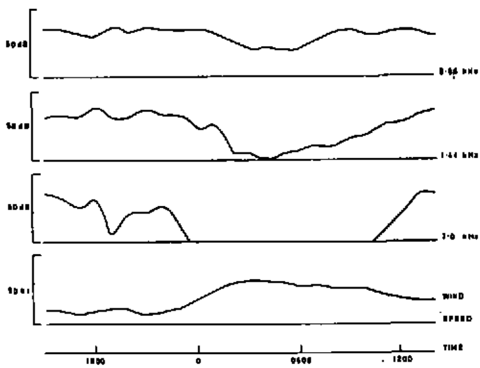
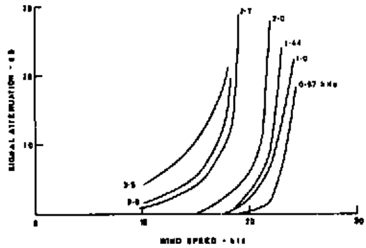
2. Glotov V.P., Kolobaer P.A., Neuimin G.G. 1962 Sov Phys - Ac. 7, 4. 341-345. Investigation of the scattering of sound by bubbles generated by an artificial wind in seawater and the statistical distribution of bubble size.
3. Marsh H.W., Schulkin M. and Kneale S.G. March 1961, Journal of Ac.Soc. Am 33-3, 334-340. Scattering of Underwater sound by the Sea Surface.



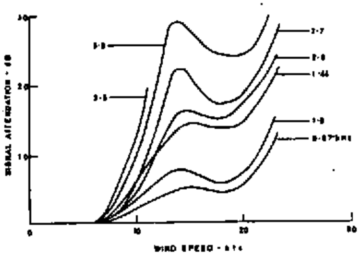
ENVELOPE OF PULSES RECEIVED OVER 23 km PATH 19-20 TH JUNE 1969

Fig. 1



DEPENDENCE OF SIGNAL ATTENUATION ON WIND SPEED AND FREQUENCY,
3 RD MAY 1967 INCREASING WIND DIRECTION 220°

Fig. 2



LOW WIND SPEED ATTENUATION PEAK 10TH SEPT 1968,
INCREASING WIND, DIRECTION 040°

Fig. 3