Spatial Coherence of Sound in Convergence Zones and Shadow Zones in Deep Water

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Abstract: Some results of a horizontal coherence experiment of sound propagation in deep water are presented. Explosive sources were used. Signals were received at a horizontal receiving array of 5 hydrophones with overall length 250m. It was found that at zone of direct arrival and convergence zones the radii of coherence were larger than 200 m. When sound sources were placed at shadow zones, radius of horizontal coherence was less than 100 m, much lower than that at convergence zones.

Experiment was conducted at deep sea with water depth about 4200m. Depth of sound channel is about 1200m. Receiving ship was drifting and from it a flexible horizontal array of 5 hydrophones with overall length of 250m was put down at depth of 200m. Distance between hydrophones were 100m, 80m, 40m and 10m. In combination we can measure the horizontal coherence of distance 10m, 40m, 50m, 100m, 110m, 150m, 210m and 250m.

We used explosive charges as sound sources and dropped explosive charges 38g at 7m depth, 1Kg at 100m, 1Kg TNT at 200 m and 1Kg TNT at 1000m, while source ship moved at speed 3-8 knots at different distance from receiving ship. Signals received from different hydrophones went through preamplifiers and band-pass filters 40-2500 Hz, and were recorded at 14 track tape recorder TEAC/50C.

When the source ship moved on we met with zone of direct arrival, shadow zones, first, second, and up to 10th convergence zones at distances of 45-55 km, 100-110 km and up to 600km. Shadow zones exist between direct arrival and first convergence zone, and between every two neighbouring convergence zones.

At zone of direct arrival signal to noise radio was closed to 20 dB. Broad band coherence coefficient at horizontal distance up to 250m was higher than 0.8. Most of narrow band coherence coefficient was higher than 0.95. At shadow zones signals were weak and signal to noise ratio were 0dB-13dB. The wave forms were complexed with length of signal up to 600 ms. Broad band coherence coefficient dropped quickly from 0.9 at distance of 10m to 0.3 at distance of 250m. As for narrow band signals coefficients of horizontal coherence were rather low. At frequencies lower than 1000 Hz coefficient of horizontal coherence at 10m was as high as 0.9. Coefficients of horizontal coherence of higher frequencies were lower than 0.5 as shown in Fig 1. Sound field at shadow zones was formed by reflection from sea bottom. It is possible that the irregularities of sea bottom caused the drop of coefficient of horizontal coherence.

Signal to noise ratio at first to fourth convergence zones were high, from 30dB to 20dB. Wave forms at convergence zones were relatively simple and length of signals was short, about 100ms. Broad band coefficient of horizontal coherence in convergence zones were relatively high (0.9) as shown in Fig 2. That was due to coherence summation of normal modes, and sound rays had no contact with sea bottom. So the signals were simple and signal to noise ratio was high. The width of coherence zone increased as distance and number of coherence zones increased. The convergence effect became weaker and weaker, so the coefficient of horizontal coherence became lower and lower.

The relationship between horizontal coherence and frequency and band width: Frequency of signals had significant influence on coefficient of horizontal coherence. General speaking, coefficient of horizontal coherence at low frequencies (100 Hz-500 Hz) was high at zone of direct arrival, convergence zones and even shadow zones, that was because the wave length of low frequencies is large and loss was low at low frequencies. Coefficient of horizontal coherence at high frequencies (750 Hz-2500Hz) were not stable. Coefficients of horizontal coherence were high at zone of direct arrival (0.9 up to 250 m). Coefficient of horizontal coherence at shadow zones were low (0.5 and some times 0.2). Coefficients of horizontal coherence at convergence zones were relatively high but not stable. For example, at frequency 1500 Hz coefficient of horizontal coherence at distance of 217 km was 0.9, but coefficient of horizontal coherence was about 0.6 at distance of 45-55km at first convergence zone. And for frequencies higher than 2000, coefficients of horizontal coherence were not stable.

Experiment shows that there were no significant influence of band-width on coefficient of horizontal coherence. The relationship between depth of source and coefficient of horizontal coherence (1):

We used explosive charges at four depth, 7m, 100m, 200m and 1000m. Experiment shows that there was some influence of source depth on coefficient of horizontal coherence. At this area the sound channel exist at depth
lower than 50m. So when source depth was at 7m, signal can be received only at zone of direct arrival and shadow zone.

When sound source were at 100m and 200m, there were very strong convergence effect and the coefficient of horizontal coherence at convergence zones were very high.

When sound source was at 1000m, close to sound channel, there were poor convergence effect. Signal was split to several impulses. The impulse with largest amplitude had good coherence, but other impulses with small amplitude have low signal to noise ratio and poor coherence.

REFERENCES


![FIGURE 1](image1.jpg) ![FIGURE 2](image2.jpg)

**FIGURE 1** Horizontal coherence at shadow zone  
**FIGURE 2** Horizontal coherence at first convergence zone