The effect of the reflection of the seabed on source signature recorded by ocean bottom nodes

Introduction

Wavelets emitted by seismic sources are called source signatures. They are required for environmental impact assessment and permitting. It is therefore important to know the maximal Sound Pressure Level (SPL) of seismic sources. SPL is in units of BarM, which is the pressure level in Bars at a nominal distance of 1 meter from the source. Assuming spherical spreading and no attenuation in water, the maximal pressure level of the far field direct arrivals at any distance is the source SPL in BarM divided by the distance in meters.

In this paper we consider pneumatic sources, mostly called Airguns. A few different methods are used to estimate Airgun signatures. One method is source modelling (Ziolkowski, 1970). A second method is calculating notional signatures from data recorded by near field hydrophones (NFH) data (Ziolkowski et al, 1982). A third method is calculating source signatures from data recorded by far field hydrophones (FFH). These different methods are used nonexclusively. Ideally, all methods agree. Each method has advantages and disadvantages.

Source modelling, in practice, reduces a three-dimensional problem to one dimension. Also, in practice, it approximates modelling of the air flow inside the source (Watson et al, 2019).

Problems with NFH methods are the approximations needed to undo the effects of interactions between sources in arrays and clusters and the effects of the ocean surface reflections, called ghosts. Another problem of NFH is that not all the pressure in the near field is radiated to the far field. For example, air leaks. The NFH method must therefore be compared to the other two methods. Note, that NFH provide source quality control in real time. So, whether their data are used in FFH data processing or not, they are needed for source quality control in real time.

FFH data are direct measurements of what marine creatures hear. This method does not suffer from the Modelling and NFH challenges. However, to estimate source signatures that can be compared to what modelling and NFH methods produce, the effects of ghost reflections from both the sea surface near the source and from the seabed near the receiver must be removed by data processing. The process is called deghosting.

In this paper we present far field data that we recorded and signatures that we estimated from these data after deghosting both the seabed and the surface reflections.

Materials and Methods

We deployed two drop and pop ocean bottom nodes called OBN0 and OBN100 (Figure 1). The boat drifted after deploying the OBNs and before shooting. OBN0 was on the seabed at a lateral distance of 2684 meters away from the nearest shot. Its depth was 2508 meters. OBN100 was floated above the seabed on a 100 meter rope connecting it to an anchor on the seabed. Its depth was 2408 meters, and it was at a lateral distance of 2550 meters from the nearest shot.

Raw data

Data from the nearest shot are shown in Figures 2-4. Instead of showing the data in raw Volts, we first scaled the Volts to Bars, and then we multiplied the data by the distance in meters from the source to each receiver. Note that the distances from the source to the receiver are different for the direct arrival (Figure 3) and for the first multiple (Figure 4). Other than scaling from Volts to BarM there is no cooking in this section. Scaling from Bar to BarM was not done by a time dependent so called tpow=1 spherical spreading gain. We scaled each trace by the distance travelled from the source to the receiver of each event. Slightly different distances between OBN0 and OBN100. Greatly different distances between the primary event (green in figure 1) and the multiple event (orange in figure 1).

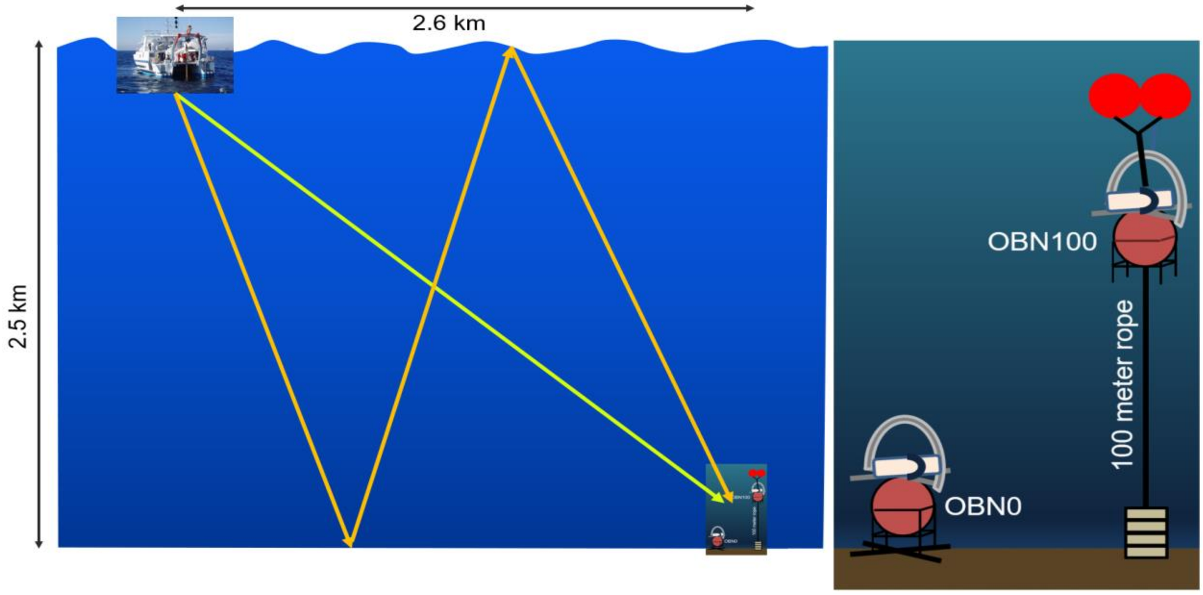

Figure 1 *OBN0 was deployed on the seabed at a depth of 2.5 km. OBN100 was hung 100 meters above the seabed. The nearest shot was at a lateral distance of 2.6km. The direct arrival and first multiple rays is are in green and orange.*

Figure 2 *Near shot data. Units: calculated BarM. OBN0 (in black) was scaled by its diagonal distance = 3674 meters. OBN100 (in red) was scaled by its diagonal distance = 3507 meters.*

Cooked data

The seabed ghost is a reflection from the seabed. It is an obvious ghost for OBN100 because its ghost delay is almost 150 milliseconds. It is annotated as “Seabed ghost (red only)”. It is not obvious for OBN0 because there is no seabed ghost delay for a node on the seabed. If all we had was OBN0 we might have “measured” maximal SPL of 9.17 BarM. We did, however, have OBN100 which “measured 5.1 BarM. When deghosting the seabed reflection we got consistent max SPL of about 5.2 BarM (Figure 5). However, this was not the end of the story. We still had to account for the source side sea surface ghost. After surface deghosting, accounting for oblique angle of offsets larger than the depth, we got max SPL of 9.25 ± 0.1 BarM (Figure 6).

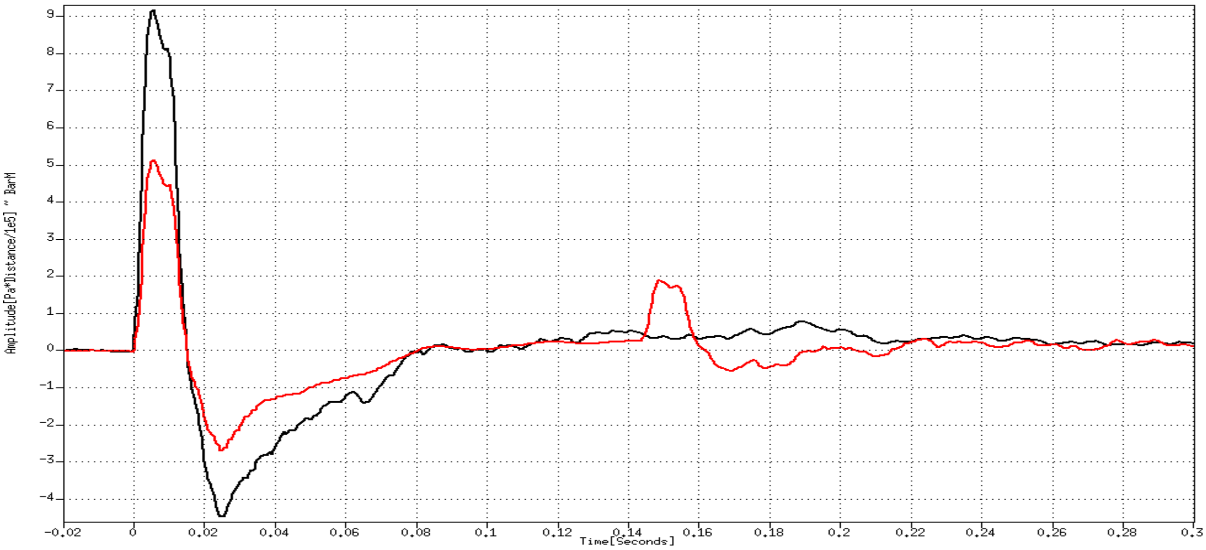

Figure 3 *Near shot data direct arrivals scaled by figure 1's green distances.*

Figure 4 *Near shot data first multiple scaled by figure 1's orange distances. The down-up-down orange distance to OBN0 was 7989 meters. OBN100's was 7661 meters. The amplitude of figure 4 is about 2.15 stronger than figure 2's. This factor would have been close to 3 for zero offset but is closer to factor 2 at these far lateral offsets that are larger than the sea depth. The seabed reflection coefficient can be calculated from the ratio between the amplitudes in figures 4 and 3.*

Discussion

If the ghost delay time is longer than the source rise time, then the ghost does not affect the recorded maximal pressure level. This is never true for seabed ghosts recorded by sensors on the seabed. This may or may not be true for surface ghosts, depending on their rise time and angle. It is true for Airguns whose rise times are just 1-2 msec, except at very wide angles or if they are deployed very shallow. Airguns are ghosted monopole sources. However, the rise time of the source that we tested, called Tuned Pulse Source, was 10 msecs. It was significantly longer than the ghost delay time at the angles that we had. Because of its long rise time and even longer air discharge time, the TPS is in effect a dipole source because of the interaction between its ghost and the air discharge. We found that surface deghosting was also required. We therefore had to deghost both the seabed near the receiver and the water-air surface near the source, before we could estimate the maximal SPL of the TPS from the data.

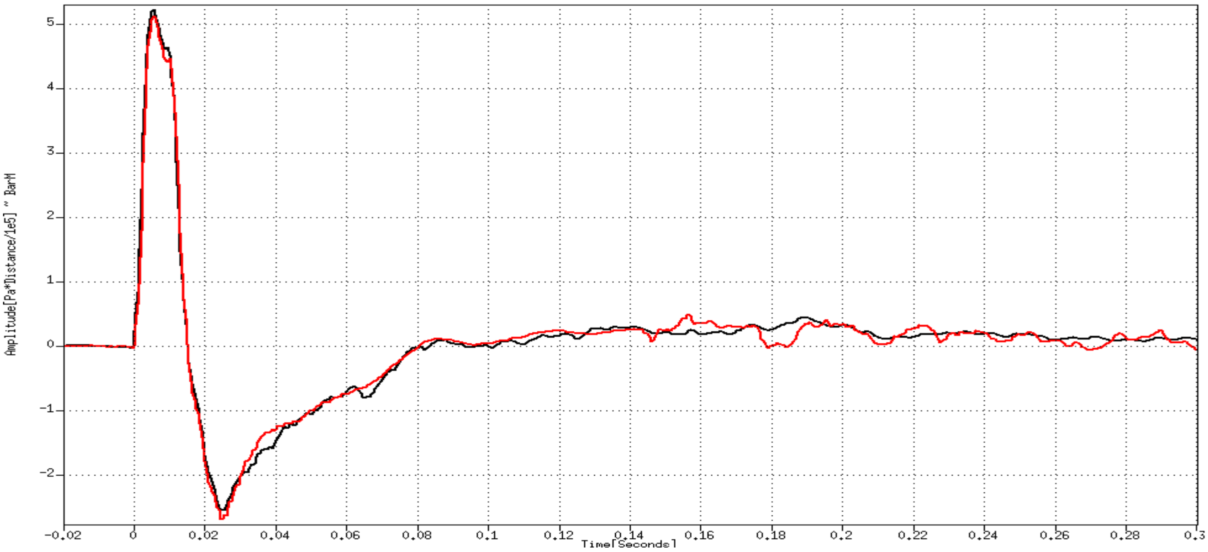

Figure 5 *Direct arrivals after deghosting the seabed reflection. Maximal SPL seems to be 5 BarM.*

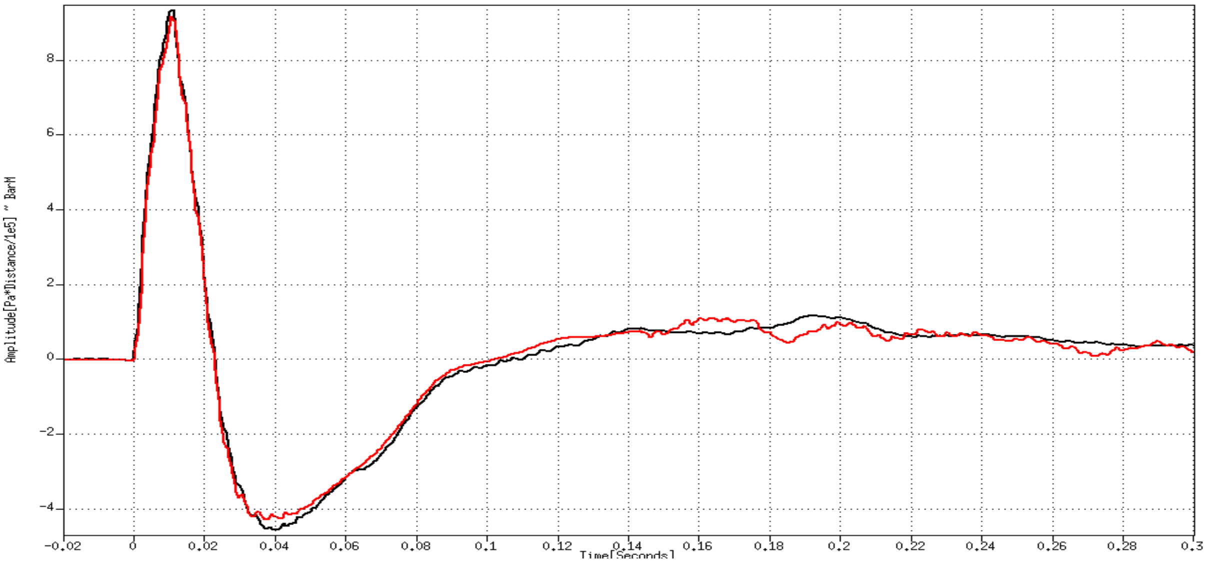

Figure 6 *Direct arrivals after deghosting both seabed and sea surface reflections. Note that in addition to the obvious scale from 5 to 9 BarM maximal SPL, there is also a difference in the wavelets shapes compared to figure 5.*

Conclusion

We rode a roller coaster from 9 BarM down to 5 BarM and then back up to 9 BarM. Deghosting the seabed is always required before one can claim that max SPL can be measured by ocean bottom data. For TPS, because its rise time was longer than its surface ghost delay, deghosting the surface ghost was also required. The effects of the seabed ghost and the surface ghost on the sound pressure recorded by an OBN are opposite and in some cases may cancel each other at certain angles.

References

Watson, L., M., Werpers, J, Dunham, E. M.,2019. What controls the initial peak of an air-gun source signature? Geophysics **84**, 27-45.

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Ziolkowski, A., Parkes, G., Hatton, L., and Haugland, T., 1982. The signature of an air gun array: Computation from near-field measurements including interactions. Geophysics **47**, 1413-1421.