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Red Ghosts and Broadband Processing

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Summary

Surface ghosts cause spectral notches. There is always a notch at 0 Hz which limits the low frequency content of the data. The objective of deghosting in data processing is to undo the physical process of surface ghosting. When scattering from irregular surfaces, such as ocean swell, is taken into account, the reflection (and transmission) coefficients become frequency dependent.

This is true for both sources and receivers. Near seismic sources, in addition to swell, particle accelerations may be comparable or even exceed the earth's gravity which is what is keeping water under air. Surface tension also plays a role.

The displacement can be large enough for stress-strain relations to become nonlinear. These nonlinear effects are frequency dependent causing the reflection coefficient to be smaller at higher frequency. Frequency independent reflection would be white but frequency dependent ghosting is red, more so near the source than near the receiver. It is useful to understand the physics of ghosting so that the relations between the up- and the down- going are understood and the up/down separation for deghosting can be made more robust.

Red ghosts and Broadband Processing

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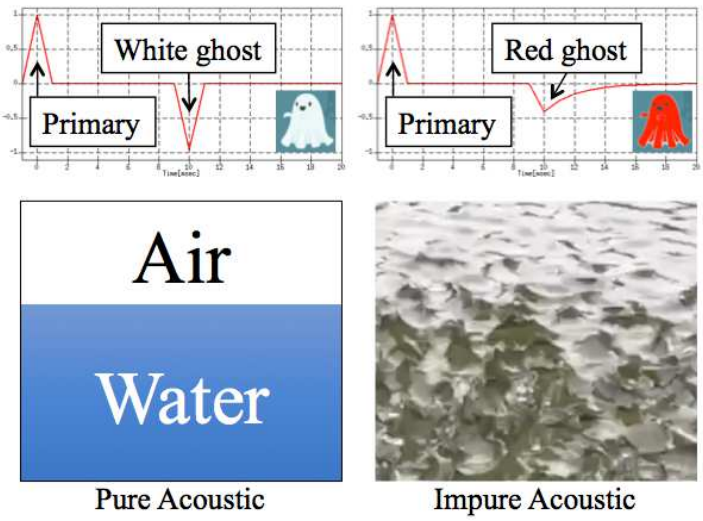

Surface ghosts cause spectral notches at f_n=750n/z, where f_n is the frequency in Hz, n=0,1,2,3… is the order of the notch, and z is the depth of the source in meters. The above formula is for vertical incidence. To account for obliquity a cosine term can be added, but it is omitted here for simplicity. For example a source at z=7.5m has a first notch at f_1=100Hz at near offsets. Whatever z > 0 is, there will always be a notch at f_0=0. The objective of deghosting in data processing is to undo the physical process of surface ghosting.

This paper is about source deghosting and not about receiver deghosting because great progress has already been made on receiver deghosting with broadband data processing relying on acquisition solutions such as 24 bit data, over/under streamers, variable depth streamers, multi-sensor streamers, and ocean bottom receivers. Another reason for more interest in source deghosting is that the physics of reflection from the air-water interface is more interesting at the source than it is at the receiver.

If the acoustic impedance of air was infinitely small compared to that of water, then the reflection coefficient of the Air-Water interface would be -1 and the source spectra would be zero at all notches. With finite impedance of air and mainly with spherical spreading, the reflection coefficient is less than 1 (in absolute value) and the spectra at the notches are small but not zero. These effects of acoustic impedance contrast and spherical spreading are frequency independent. If scattering from irregular surfaces, such as ocean swell, is taken into account, the reflection (and transmission) coefficients become frequency dependent. This is true for both sources and receivers, but near seismic sources, in addition to swell, particle accelerations may be comparable or even exceed the earth's gravity of 9.81m/s^2. Since the earth gravity is what is keeping water under air, the physics is more interesting and surface tension also plays a role. It is captured by the image of the water surface near a seismic source shown at the lower right part of the figure above. These nonlinear effects are frequency dependent causing the reflection coefficient to be smaller at higher frequency. Frequency independent reflection would be white but frequency dependent ghosting is red, more so near the source than near the receiver.

It is known that near field hydrophones in over/under configuration are useful for deghosting because up/down separation can be performed. It is useful to understand the physics of ghosting so that the relations between the up- and the down- going are understood and the up/down separation can be made more robust.