Can we detect fish in the ocean the same way an ultrasound machine gives an image of a beating heart? Or can we get an ultrasound image of a whole organ in 3D? Such are the questions that this thesis contributes to answer by studying a particular property of sound propagation, its nonlinearity.

Sound is used similarly with sonars in underwater acoustics or with ultrasound imaging in medicine. As the sun light is reflected when hitting the surface of the sea, the sound sent through the ocean or through the body is reflected by the sea floor or by the organs. By analyzing this reflected sound, the echo, an image from the object that reflected it can be built.

When the sound propagates through water or biological tissue, it undergoes a transformation due to nonlinear effects. The effects of nonlinear sound propagation have been known for long. But in many cases, they appear as a disturbance that is either ignored or avoided. In a few applications, though, these effects have been exploited. In medical ultrasound imaging, they have given better image quality using what is called Tissue Harmonic Imaging or THI. And in underwater acoustics, they have given the possibility to image several hundred meters below the ocean floor using parametric sonars. This thesis tries to extend the field where nonlinear effects can be put to use.

Like the brass band against the solo trumpeter, the nonlinear effects make the received signal “richer”. More information can be extracted from it. This can translate to a better resolution and decrease the minimum size of the fish an echo-sounder can detect. Or it can allow a more precise estimate of the ocean current speed. The extra information can also help classifying the fish detected by sonars on a fishing boat.

The better resolution and lower perturbations obtained when exploiting the nonlinear effects can also be used to decrease the number of signals needed to create a 3D image of an organ. Fewer signals needed means the image can be updated faster and accurately reproduce the movement of a beating heart in 3D.