Dolphin algorithm could lead to better medical ultrasounds

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Millions of years of evolutionary fine-tuning have made dolphins phenomenally good at using echolocation to orient themselves, find food and communicate with one another. But how do they actually do it? New research from Lund University in Sweden shows that they emit two intertwined ultrasound beam components at different frequencies—and with slightly different timing.

This new knowledge brings us one step closer to solving the puzzle. A few years ago, Josefin Starkhammar, a researcher in biomedical engineering at Lund University, discovered that the ultrasounds that dolphins emit for echolocation do not consist of one signal, but rather of two intertwined beam components.

Her most recent calculations now show that the two signals are not emitted at exactly the same time, although they follow one another very closely. Likewise, she has discovered that the sound frequency is higher further up in the beam, producing a lighter echo within that area.

"High and low frequencies are useful for different things. Sounds with low frequencies spread further under water, whereas sounds with high frequencies can provide more detailed information on the shape of the object," explains Starkhammar.

Starkhammar suggests there could be multiple benefits for the dolphin: The time-separated signal components may enable the animal to quickly gauge the speed of approaching or fleeing prey, as the variations in frequency provide more precise information on the position of an object. However, the researchers do not yet know whether this is, in fact, the case.

Josefin Starkhammar worked with Maria Sandsten and Isabella Reinhold, professor and doctoral student respectively, in mathematical statistics. Together, they developed a mathematical algorithm, which was used to successfully disentangle and read the overlapping signals.

"It works almost like a magic formula! Suddenly we can see things that remained hidden with traditional methods," says Josefin Starkhammar.

Not only does the algorithm increase our understanding of dolphin communication, it could also pave the way for sharper image quality on ultrasound technology built by humans, such as medical ultrasound. It could potentially be used to measure the thickness of organ membranes deeper inside the body, for which current methods are insufficient.

Another possible area of improvement is sonars and echosounders, i.e. the equipment used for orientation at sea to read the undersea environment and track shoals of fish.

"Here we could copy the principle of using sound beams whose frequency content changes over the cross-section. As a first step, we will rebuild our own equipment which is based on the pulse-echo principle," says Josefin Starkhammar.

Together with researchers in engineering geology, Josefin Starkhammar also has plans to trial the technology as a replacement for destructive testing of roads, for example by rapidly obtaining an image of what a newly-built road looks like under the surface without needing to drill for samples.

Even the dolphins themselves are helped by humans better understanding their echolocation capabilities.

"With greater understanding, we can protect them from human activity which could damage, disrupt or disable this ability, such as noise from shipping, pile driving in the water, underwater blasting, powerful boat sonars and searching for oil under the sea bed using acoustic methods," says Josefin Starkhammar.

The researchers don't yet know how the dolphin actually sends out its two almost simultaneous beam components.

"In fact, it is quite strange that the dolphin emits two different beam components, as they come from the same organ. We would very much like to find out how this particular event comes about," she concludes.

In order to gather data, Josefin Starkhammar built a measuring instrument with 47 hydrophones (microphones for underwater use) which capture sounds in water in many different frequencies over a whole surface, for example over the whole cross-section of dolphin sonar beams. The dolphin sounds were recorded in Kolmården Wildlife Park in Sweden and in wildlife parks in the Bahamas, Honduras and California.

More information: Isabella Reinhold et al. Objective detection and time-frequency localization of components within transient signals, *The Journal of the Acoustical Society of America* (2018). DOI: 10.1121/1.5032215

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