Water waves exhibit negative gravity near a periodic array of buoys

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Scientists have discovered a new mechanism to block water waves, which could be used to extract energy from ocean waves.

(PhysOrg.com) -- Ocean waves can be incredibly strong and very difficult to block completely. When a wave moving across the ocean interacts with a buoy, the wave can be slightly dampened, but will still pass by if its wavelength is long enough compared to the size of the buoy. But in a new study, scientists have calculated that a periodic array of resonators (such as vertical bottom-mounted split tubes or damping buoys) resonating at a low frequency can completely block water waves.

The effect arises from the water having negative effective gravity.

The researchers, Xinhua Hu from Fudan University in Shanghai, China, and coauthors from China and the US, have published their study in a recent issue of Physical Review Letters.

Through mathematical calculations and numerical simulations, the researchers have shown that, when a periodic array of vertical bottom-mounted split tubes resonates near a certain low frequency, the array strongly reflects approaching water waves. They found that such a strong reflection can dramatically modify the absorption efficiency of the waves.

“It is a surprising result that a periodic structure can block long-wavelength water waves (namely, with wavelength longer than the periodic length) because conventional periodic structures such as a periodic array of bottom-mounted cylinders cannot block long-wavelength water waves,” Hu told *PhysOrg.com*. “In order to block long-wavelength water waves, the building block of the structure should have a low resonant frequency or a long resonant wavelength. Bottom-mounted split tubes or heaving buoys can present such a low-frequency resonance.”

As the researchers explain, because the water waves cannot pass through the periodic array of resonators, it’s as if the water has negative effective gravity.

“The gravity is usually positive or pointed to the center of the Earth,” Hu explained. “Effective gravity is a parameter in our effective medium theory for long-wavelength water waves propagating through a periodic structure. The effective gravity is also usually positive for conventional periodic structures such as a periodic array of bottom-mounted cylinders.”

Although the researchers' simulations involved the split tubes as resonators, they predict that other resonators such as damping buoys would have the same effect. Buoys that can block water waves could be used to extract ocean wave energy, and play a key role in future ocean wave power plants.

"Although current researches focus on improving the efficiency of a single resonator, an array of damping resonators is regarded as a key part of future ocean wave power plants," Hu said. "Our work reveals that the absorption spectrum of an array of damping resonator (two absorption peaks) is quite different from that of a single damping resonator (one absorption peak). Such a modification is not expected by engineers on ocean wave energy extraction. Knowing such a modification is important for the future design of the resonator in ocean wave power plants."

Hu added that the research group has experimentally verified the predicted results, which will be published in an upcoming paper.

More information: Xinhua Hu, et al. "Negative Effective Gravity in Water Waves by Periodic Resonator Arrays." *Physical Review Letters* 106, 174501 (2011). DOI:10.1103/PhysRevLett.106.174501

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