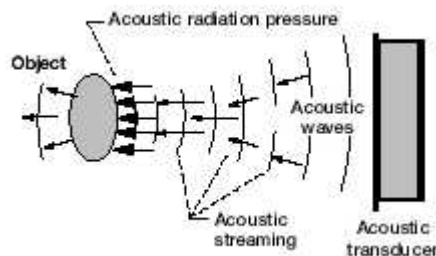


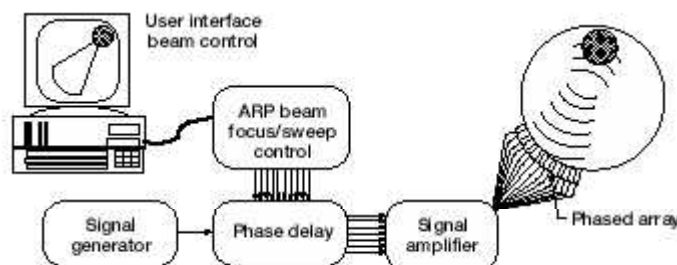
Manipulating Liquids With Acoustic Radiation Pressure Phased Arrays



Acoustic Radiation Pressure.

High-intensity ultrasound waves can produce the effects of "Acoustic Radiation Pressure" (ARP) and "acoustic streaming." These effects can be used to propel liquid flows and to apply forces that can be used to move or manipulate floating objects or liquid surfaces. NASA's interest in ARP includes the remote-control agitation of liquids and the manipulation of bubbles and drops in liquid experiments and propellant systems.

A high level of flexibility is attained by using a high-power acoustic phased array to generate, steer, and focus a beam of acoustic waves. This is called an Acoustic Radiation Pressure Phased Array, or ARPPA. In this approach, many acoustic transducer elements emit wavelets that converge into a single beam of sound waves. Electronically coordinating the timing, or "phase shift," of the acoustic waves makes it possible to form a beam with a predefined direction and focus. Therefore, a user can direct the ARP force at almost any desired point within a liquid volume.



Acoustic Radiation Pressure Phased Array (ARPPA) system.

ARPPA lets experimenters manipulate objects anywhere in a test volume. This flexibility allow it to be used for multiple purposes, such as to agitate liquids, deploy and manipulate drops or bubbles, and even suppress sloshing in spacecraft propellant tanks.

NASA Lewis Research Center's ARPPA technique uses an all-digital form of phase shifting to achieve the desired beam steering and focusing. Instead of using expensive phase shift circuits to control the acoustic waves and the beam shape, ARPPA forms the beam as a series of digital words in computer memory. A simple algorithm is used to calculate the desired beam focus and steering angle. Then, an off-the-shelf digital word generator is used with a reference frequency source to clock the pattern at the desired

frequency. The signal is amplified from logic-level voltages to well over 100 V. The high-voltage signals are used to drive the acoustic phased array. Each channel has a separate amplifier to drive each individual array element. Users can operate the system interactively by using a computer mouse or similar input device. When complete, the system should be able to track an object and apply the ARP force to manipulate its position and behavior in real time.

Because this system is nonintrusive, users can manipulate liquids or objects without opening the containers, making it possible to safely handle many toxic or reactive chemicals. Consequently, ARPPA has many potential ground-based applications in the handling and agitation of liquid slurries in the production of chemicals and paints.

The technique can also be used to create standing surface waves like those used for applying coatings and solders to electronic circuit boards. The ability to alter the surface wave on command may make it possible to eliminate masking operations. This, in turn, would reduce tooling costs and chemical waste products.

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