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Bubble-Based Resonance-Doppler Sensor for Liquid Characterization

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Abstract: I have developed a novel technique that can monitor all stages of an air bubble's evolution, from its formation and growth at a nozzle, through its detachment and resonance, to its rise toward terminal velocity, in order to derive multiple physical properties of the surrounding liquid. Other methods, such as high-speed photography and laser Doppler anemometry can study only one aspect of the bubble evolution. This technique, on the other hand, uses passive acoustic listening combined with active ultrasonic Doppler observation to study all aspects of the evolution. The setup consists of a metal syringe needle positioned vertically at the bottom of a water- filled tube. A small aquarium pump forces air through the needle, forming a series of evenly spaced, mm-sized air bubbles. A hollow cylindrical transducer is located around the needle and a dual-element transducer is positioned several centimeters above the tip of the needle. To continuously monitor the motion of the bubbles, I constructed a frequency-mixing based Doppler system and used the Short-Time Fourier Transform technique. The cylindrical transducer detects the resonance of the bubble following its detachment. The Doppler setup detects both the growth and rise of the bubble, including shape oscillations and the terminal velocity. All steps in the evolution of the bubble are affected by the presence of contaminants (surfactants, suspended particles, and alcohol). Each measurement agrees well with theory. This technique has a real potential for use as a novel liquid characterization sensor in many industrial applications (e.g. chemical, environmental, food, and medical).