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Darren W. Branch

Sandia National Laboratories
PO Box 5800, MS-1425
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Time-Reversal Change Detection and Rapid Multiphysics Models for Next-Generation Acoustic and Magnonic Devices

This talk presents wave-based sensing and fast modeling methods spanning time-reversal acoustics, nonlinear piezoelectric tuning, and magneto-acoustic device physics. I describe a time-reversal acoustics (TRA) measurement system for detecting change events in complex environments where optical line-of-sight is blocked. The system detected both gross changes (e.g., removing an object from a dense "forest" of posts) and subtle tampering (e.g., material substitution), with sub-wavelength spatial sensitivity. Simulation tools revealed object and boundary interactions encoded in the time signals and quantified the impact of sensor geometry and boundary conditions on detection and localization. Second, we developed simulation capability to predict tuning in nonlinear RF devices, demonstrated voltage-controlled frequency tuning in X-cut lithium niobate (LN) on insulator, and created tools for nonlinear coupling analysis. A key outcome is capturing nonlinear effects with effective-medium properties, enabling applications such as real-time RF device temperature stabilization. Third, I motivate acoustically driven ferromagnetic resonance (ADFMR) for energy-efficient control of magnonic devices via magnetoelastic coupling driven by piezoelectric transducers. Lastly, I describe fast simulation approaches for magneto-acoustic devices using perturbation theory and a Stroh-formalism framework for efficient modeling of magnetoelastic layered media.

Bio

Dr. Darren W. Branch is a Distinguished Member of Technical Staff at Sandia National Laboratories. He earned a B.S. in Physics from the University of California, San Diego (1994) and a Ph.D. in Biophysics from the University of Illinois at Urbana–Champaign (2000). Dr. Branch has over 26 years of experience in sensors, biosensors, microfluidics, and MEMS devices, including surface acoustic wave, piezoelectric and ferromagnetic devices, Lamb and bulk wave resonators, transducer design, and RF sensors. He also has extensive experience developing fast computational and simulation tools for acoustic, piezoelectric, and RF devices. He received two R&D 100 Awards for Acoustic Wave Biosensors for Rapid Point-of-Care Medical Diagnostics and another R&D 100 Award for Microresonator Filters and Frequency References. He was the lead Sandia investigator, in collaboration with Qorvo Biotechnologies, to develop and commercialize the Omnia™ point-of-care diagnostics platform. Dr. Branch has served as PI on twelve Collaborative Research and Development Agreements (CRADAs) focused on commercializing Sandia-developed technologies. He has authored over 100 publications and holds 24 patents (27 licenses executed), spanning acoustic, strain-based, RF/microwave, piezoelectric, magnetic-based devices, and biosensors.

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